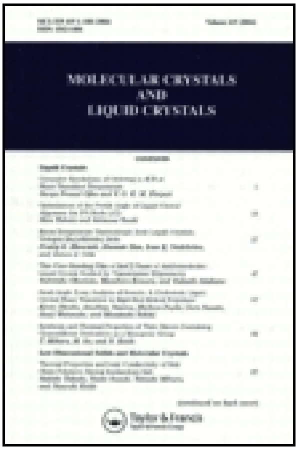

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Effect of surface-Induced Anchoring on Nic Light Scattering Characteristics

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EFFECT OF SURFACE-INDUCED ANCHORING ON NLC LIGHT SCATTERING CHARACTERISTICS

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Abstract The effect of surface anchoring energy on NLC light scattering cross-section and temperature dependence of anchoring parameter are discussed.

INTRODUCTION

Study of the NLC-solid surface interaction is important for the understanding of LC molecular aligment mechanism and is stimulated by practical applications. LC devices' technical parameters such as 'relaxation time, information capacity, stability, depend on many characteristics but the basic one is the NLC surface-induced alignment and anchoring energy in the vicinity of the interface.

Many works have been devoted to the developing of the reliable method of anchoring energy determination. The common feature of all techniques is using of some external impact (mechanical deformation[1], surface defects creation[2], external electric[3], or magnetic[4] fields) in order to force the NLC director to deviate from its equilibrium value. Thus deformation of the NLC sample and new director distribution during anchoring measurements take place, that lovered the reliability of the values obtained, as they may differ from those corresponding to equilibrium crystal.

ANCHORING AND SCATTERING

Recently it was shown that due to the long order intermolecular forces, interaction between NLC molecules and solid surface affects nematic director fluctuations[5]. The spectrum of the fluctuations depends on the boundary conditions which are determined to some extent by the value of anchoring energy. Macroscopically this dependence becomes apparent in low angle light scattering on the nematic director fluctuations.

Theoretical investigations and experiment performed clarify the dependence of the scattering cross section σ on the value of the anchoring energy[5].

The differential cross section for unit volume is[6]:

$$\sigma = \pi^{-2} \lambda^{-4} \varepsilon_a^2 \sum_{\alpha} (i_\alpha f_{\parallel} + i_{\parallel} f_\alpha)^2 \langle \delta \underline{n}^2(\underline{Q}) \rangle \ , \qquad (1)$$

where $\delta \underline{n}_\alpha$ - director fluctuation amplitude, $\varepsilon_\alpha = n_e^2 - n_o^2$ - dielectric constants anisotropy, n_e, n_o - refraction indexes for the ordinary and extraodinary waves, $\alpha = 1,2$; $(i_\alpha f_{\parallel} + i_{\parallel} f_\alpha)$ - geometry factor, i,f - polarization states for the incident and scattered light; $i_\alpha = \underline{ie}$, $f_\alpha = \underline{fe}$; $\underline{e}$ -

vectors of coordinate system, perpendicular to Z-axis, parallel to director, $\underline{Q}$ - scattering vector, lies in eZ-plane, $f_{\parallel}$, $i_{\parallel}$ - progection of $\underline{f}$ and $\underline{i}$ on Z-axes.

To obtain the spectrum $\underline{n}(\underline{Q})$ one constant approximation was used and the difference between order parameter in the bulk and near interface was neglected. Let us consider the cell subsrate is taken as Y-axes. The energy needed to torque the director in substrate plane, W_x, and in plane perpendicular to it, W_y, may be sufficiently different and so the elastic energy of the uniform torque of the director with respect to the cell "easy axis" is

$$F = (W_x n_x^2 + W_y n_y^2)/2.$$

Full energy of the NLC layer:

$$F_f = (K\int dv((\mathrm{div}\,\underline{n})^2 + (\mathrm{rot}\,\underline{n})^2 + \int_{S_1,S_2} ds(W_x n_x^2 + W_y n_y^2))/2\,, \qquad (2)$$

where s_1 and s_2 - identically treated substrates. The equlibrium director distribution in the bulk and at the interface is obtained from the condition of minimum F_f. In particular, for small nematic director fluctuatious the boundary conditions are

$$\mathrm{div}\,\delta\underline{n} \pm \frac{W_y}{K}\delta n_y = 0\,, \qquad (3a)$$

$$\frac{\partial(\delta n_x)}{\partial y} - \frac{\partial(\delta n_y)}{\partial x} \pm \frac{W_x}{K}\,\delta n_x = 0\,. \qquad (3b)$$

Different signs correspond to two surfaces. The procedure of solving (2) accounting (3) yields the dependence of mode spectrum n(q) on the anchoring energy W. Here q is a wave vector of elastic deformation mode of the director in the cavity filled by NLC and formed by two cell surfaces. If $W \to \infty$ the spectrum is fully determined by cell thickness and is a set of equidistant positions $q_{ym} = \pi m/L$, but the effect of finite anchoring, leads to the displacement of q-values, which depends on the value of anchoring.

The expression for the light-scattering cross section with different states of polarization of the incident and scattering light σ_{eo} (e-o scattering) and the same one, σ_{ee}, (e-e scattering) enables us to calculate the relations between scattering angle θ and cross-section σ for different W (fig.1).

A fit of the experimental data and theoretical curves allows to determine the anchoring energy for some NLC. In fig.1 the experimental points for NLC MBBA and two-component mixture of athoxi-compounds (mixture A) are plotted. Cells with unidirectional rubbing were used for both NLC. Corresponding values of W are $(5 \pm 2).10^{-4}$ erg cm^{-2} (MBBA), $(5 \pm 4).10^{-3}$erg cm^{-2} (mixture A) As is obvious in fig.1 the difference in anchoring energy sufficiently affects the scattering intensity spectrum in the region of low scatte-

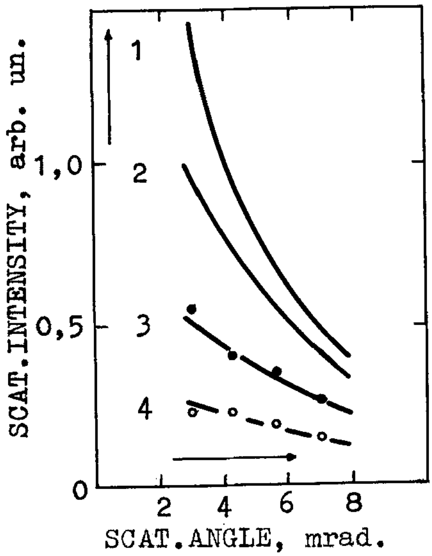

FIGURE 1. 1 $-W=5\cdot10^{-5}$ erg/cm^2, 2 -10^{-4}, 3 $-5\cdot10^{-4}$, 4 $-5\cdot10^{-3}$.

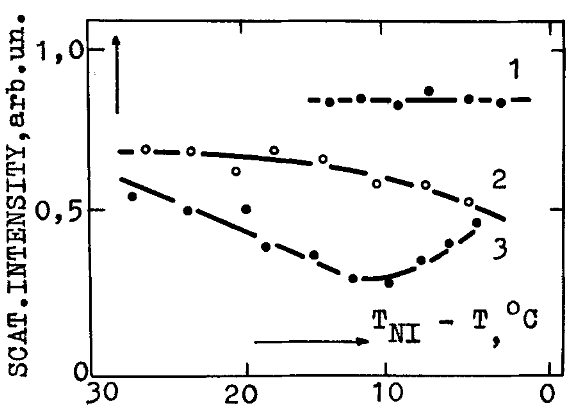

FIGURE 2.

ring intensity spectrum in the region of low scattering angles. The effect is particularly significant for e-e scattering. To illustrate the rezult we rewrite the simplified expression for σ , valid for the week anchoring and small scattering angles:

$$\sigma_{eo} \simeq (\pi^{-2}\ \lambda^{-4}\,\varepsilon_a^2 v k_B T \mathrm{Cos}^2\beta)/(\frac{2W_x}{L} + \frac{4\pi^2}{\lambda^2} K(n_e n_o\,\theta^2 + (\Delta n)^2), \tag{4a}$$

$$\sigma_{ee} \simeq (\pi^{-2}\ \lambda^{-4}\,\varepsilon_a^2 v k_B T \mathrm{Sin}^2(2\beta))/(\frac{2W_y}{L} + \frac{4\pi^2}{\lambda^2} K n_e^2\,\theta^2). \tag{4b}$$

The equatious show that the possibility to notice the influence of the anchoring energy on light scattering characteristics is determined the ratio between surface and volume energy (the second term in the denominator of (4a,b))and could be realised when their values are comparable, so for small θ . Simultaneously for scattering angles the bulk energy is always larger than in the case of e-e scattering and is not equal to zero even for θ =0. Thus for all θ the anchoring affects the characteristics of e-e scattering much more than e-o scattering.

ANCHORING AND TEMPERATURE

Recently it has been shown that anchoring energy depends on temperature[4]. But often there only exists a possibility to discuss temperature dependence of the anchoring parameter $\xi = WL/K$ because elastic constants K also change with temperature and in some cases this function is not known. An attempt to observe the dependence W(T) has been made for NLC MBBA on surfactant--treated surface[4]. It follows from the data obtained that in this case ξ was independent of temperature, i.e. the same temperature dependence for the anchoring energy and elastic constant. For NLC 5CB on the surface with obliquely evaporated SiO the analysis of the relation between values of saturated field and temperature in the electric field-induced Freedericks transition indicates that the value of ξ decreases when temperature becomes lower[5]. It means the more sharp temperature dependence for anchoring energy than for elastic constant.

During NLC light scattering experiments we have obtained different temperature behavior of the anchoring parameter. For the NLC MBBA and 5 CB, for example, the small angle scattering intensity was unchanged when temperature increased (fig.2, curve 1). It means the absense of temperature dependence for ξ and so the same low of changing of W(T) and K(T). For mixture **A** at θ = const = 3,5 mrad temperature increasing from $T = 25^{\circ}C$ to $T_{NI}-T = 4^{\circ}C$ (fig.2, curve 2) reduced the scattering intensity approximately by a factor of 1,22. By fitting the theoretical curve to the experimental results we could estimate that it corresponds to 2,2 times increase of the anchoring parameter. It means slower than for the K(T) decreasing, almost invariability, of W(T). Complicated behavior of the scattering was obtained for seven-compound-mixture of alliloxicyanobiphenils (curve 3 at fig.2). At this case the comparison with theory is difficult and the dependence has to be examined more fully.

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