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On the Electrophysical Properties of Polycomponent Mixtures Exhibiting the Smectic A Phase

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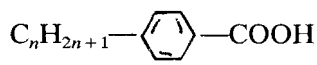
The electrohydrodynamic instability to be induced by dopant with structural formula in a smectic A phase has been studied.



A correlation between the agent circuit alkyl length and the electrooptic characteristics has been established.

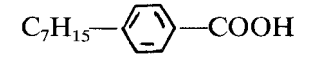
The electrohydrodynamic instability uncovered in some liquid crystal smectic A phase[1,2] and caused to carry out the memory electrical-invertible effect has been applied in the important domains.[3,4]

It should be noted that, first, the effect has been found in the liquid crystal to be the nitrophenylbenzoate.

Then, it is shown that to introduce a certain dopant the electrohydrodynamic instability can be induced in those smectic A in which this phenomena has not been observed.

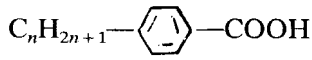
In this case of appearing, the effect the dopant is enable to control the electrohydrodynamic instability characteristics.

In the given paper we have studied only a dopant to be the nitrophenylbenzoate acide of the structural formula:



There is difficult to discuss on the dopant properties inducing the electrohydrodynamic instability, on the varying of the electrohydrodynamic instability[6] in the homologous range of the introduced dopant.

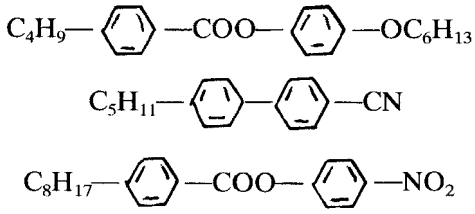
This problem is of great importance both in point of view of the experience and of the electrohydrodynamic instability of the homologous range of



depending on the homologous number of n. The corresponding measurements have been obtained.

EXPERIMENT

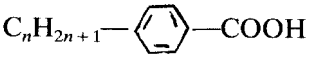
The liquid crystals exhibiting the smectic A(S_A) phase being investigated have the following structural formulae:



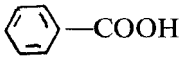
and the following phase transition

$$C \underset{50°C}{\overset{57°C}{\rightleftharpoons}} S_A \xrightarrow{69°C} N \xrightarrow{75°C} I$$

The homologous range alkoxybenzoate acide



and the benzoate acide



have been used as admixtures.

Due the high fusion temperature of the given dopant the mixtures to be prepared are solved in the keltone to further evaporating.

The obtained admixtures are of 4 mole percents. The measured cell is of a "sandwich" structure in which the films of S_nO_2 are used as electrodes. The efficient area is S = 1 cm, the thickness is d = 10 μm. The phase transition temperatures are found to observe the sample texture under the polarizing microscope. Its accuracy is ±0.1 C. The cell electroconductivity and capacity have been measured respectively by altering current bridge of E8-2 at the frequency f = 1 kHz.

The electroconductivity and the dielectric susceptibility have been calculated. To observe the cell as condenser and to take in account its geometry.

A voltage of U = 100 V and of the frequency f = 2 kHz has been applied in order to obtain the homeotropic texture.

The focal-conic texture has been obtained through the electrohydrodynamic instability stage at the low-frequency voltage.

The ratio of the electroconductivity in the focal-conic and homeotropic texture is σ_c/σ_n. The dielectric susceptibility anisotropy is

$$\Delta\varepsilon = \varepsilon_h - \varepsilon_c.$$

The threshold voltage of the electrohydrodynamic instability of U and of the focal-conic and homeotropic transition. $U_{th}^{c\text{-}h}$ have been measured by multiplier-68 for varying the sample transmittance. The measurement accuracies of U_{th} and of $U_{th}^{c\text{-}h}$ are ± 1 V and 6.5 V, respectively.

EXPERIMENTAL RESULTS

The phase transition temperatures of the "clean" nitrophenyloxybenzoate (NPHOOB) and of the doped NPHOOB depending on the dopant chain length is shown in Figure 1. In the insertion of the figure the phase transition temperature of this admixture have been given.

Figure 1 shows the dependences of the electrohydrodynamic instability threshold voltages and of the mixture focal-conic and homotropic transition (NPHOOB + 4 percent of the admixture) on the number of the homologous range.

It is seen in the figure decreasing the electrohydrodynamic instability threshold with increasing of "n". We take a minimum value for $n = 5$ further increasing to be saturated.

In this same figure the sign of (x) shows the threshold for the "clean" NPHOOB. It should be noted the threshold being high, the instability evaluating irregularly and accompanying by insignificant increasing of the optical density. So to use these methods it is not possible to measure so another parameter of the "clean" NPHOOB as $U_{th}^{c\text{-}h}$, σ_c/σ_n, $\Delta\varepsilon$, σ_c.

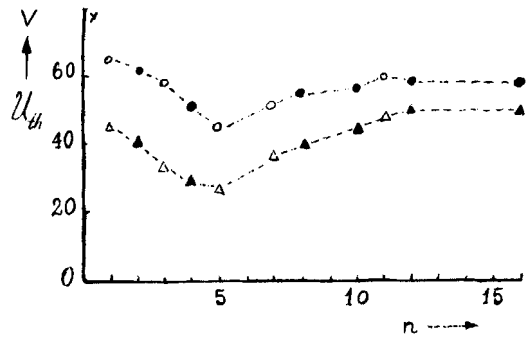


FIGURE 1 The dependence of electrohydrodynamic instability threshold voltages (○ ●) and of the confocal-homeotropic transition (△ ▲) on the introduced admixture homologous series number. The sign (x) shows the undopped mixture electrodynamic instability threshold.

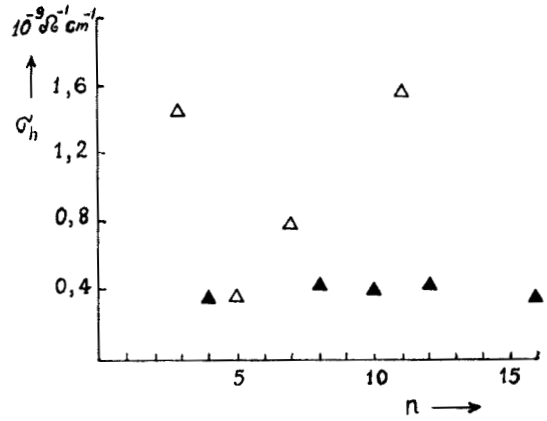


FIGURE 2 The homeotropic texture electroconductivity in dependence of the dopant homologous series number.

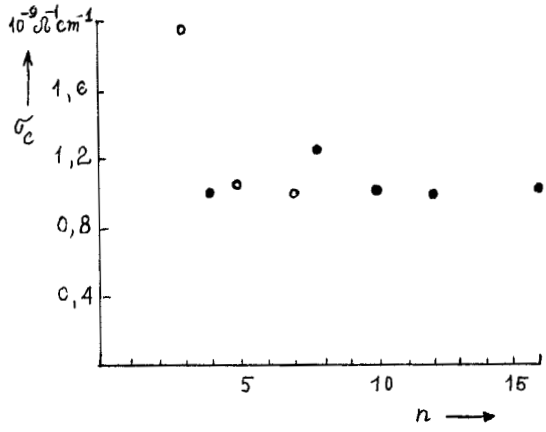


FIGURE 3 The focal-conic texture electroconductivity versus the dopant homologous series number.

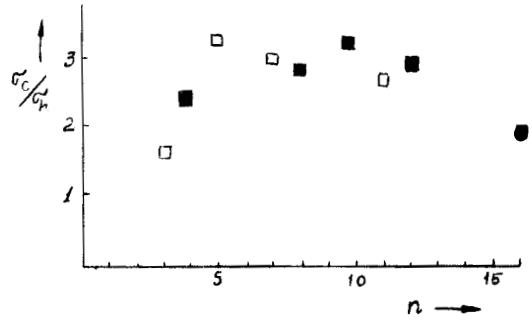


FIGURE 4 The electroconductivity anisotropy to be determined as focal-conic and homeotropic texture electroconductivity versus the introduced dopant homologous series number.

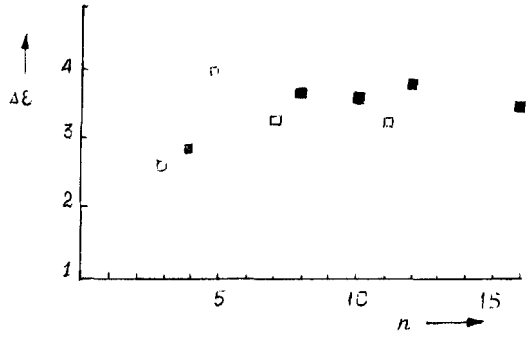


FIGURE 5 The dielectric anisotropy versus the dopant homologous series number.

As is shown in Figure 1, the focal-conic to homeotropic transition threshold decreases with increasing $n \lesssim 5$.

For $n = 5$ there is a minimum value further increasing with increasing of "n". To make clear the threshold voltage we have measured so the liquid crystal parameters as the electroconductivity of the homotropic (σ_h) and of the focal-conic (σ_c) textures and of the dielectric anisotropy of $\Delta\sigma$. The results of this varying are given in Figure 2.

DISCUSSION OF THE RESULTS

The figure shows the electrohydrodynamic instability threshold voltages (Figure 1) to be correlated to the electroconductivity anisotropy of σ_c/σ_h.

To interpret this dependence, one can use the Guerst Guussens's theory elaborated on the basis of the smectic liquid crystal continuum theory[7] and to explain the general conformities of the electrohydrodynamic instability.[5,6,8]

The electrohydrodynamic instability threshold voltage is given by the formula:

$$U_{th}^2 \frac{2q^2K\varepsilon_\perp d^2}{\varepsilon_\parallel(\sigma_\perp - \sigma_\parallel)\tau_\parallel} \cdot \frac{1 + \omega^2\tau_\perp^2}{1 - \omega^2\tau_\perp\tau_a} \tag{1}$$

where

$$\tau_\perp = \frac{\varepsilon_\perp}{4\pi\sigma_\perp}; \quad \tau_a = \frac{\Delta\varepsilon}{4\pi(\sigma_\perp - \sigma_\parallel)}$$

q is the wave vector of the appeared deformation, K is the elastic coefficient. The indices of $\perp$ and $\parallel$ show the short and long axes, respectively.

We have measured the electrohydrodynamic instability at the frequency of $f =$

26 Hz. To take in account the liquid crystal parameters of $\sigma = 10^{-9}$ ohm^{-1} cm^{-1}, $\varepsilon_\perp = 10$, $\Delta\varepsilon = \varepsilon_\parallel - \varepsilon_\perp \approx 7$, we obtain

$$\begin{cases} \omega^2\tau_\perp^2 >> 1 \\ \omega^2\tau_\perp\tau_a >> 1 \end{cases}$$

In this case formula 1 is transformed to the following

$$U_{th}^2 = \frac{\delta\tau_1 q^2 K d^2}{(1 - \frac{1}{\sigma_\perp/\sigma_\parallel})\varepsilon_\parallel}$$

It is shown decreasing the electrohydrodynamic instability with increasing of $\sigma_\perp/\sigma_\parallel$ (or σ_c/σ_h) in data formula.

The theoretical conclusion is an attractive fits to the experimental results i.e. the electrohydrodynamic instability to be correlated to the electroconductivity anisotropy variation (Figures 1–5). Thus, a minimum value of the threshold of the maximum value is obtained for this mixture.

In Figure 2 is shown the electroconductivity measured along the long axes of molecules of (σ_h).

The data matrix, i.e., the nitrophenylbenzoate is assigned to the so-named two-layered smectics.[9] Due to the strong interaction between layers, the similar smectics have the small electroconductivity anisotropy close to one. That's why the above-mentioned smectics do not make devide the space charge to necessary for occurring the electrohydrodynamic instability.

We suppose that to distort a smectic A phase layered structure play an essential role of the introduced dopant molecules of NPHOOB. The conductivity is constant practically along the smectic layers while the one varies a few to be perpendicular to the layers of some terms of the homologous range (Figure 3).

Due this fact the packing of different term molecules of the homologous range being in the matrix and the smectic layers are distinguished, respectively.

Thus, the data of this paper arise, first, choosing the optimal dopant ($n = 5$) in order to induce the electrohydrodynamic instability. Second, we have concluded that the dopant molecules introduced in the interface make distort the smectic layers. In this case the dopant of the short molecules are more efficient for measuring the electroconductivity anisotropy. Unfortunately, at present the dopant molecule – smectic matrix interaction has been till no clear completely in detail.

The molecule polar fragments are of great importance for distorting the smectic layers.

The more long molecules introduced in the smectic layer join the layers and smooth the obtained distortion. That's why the electroconductivity anisotropy measured is not of great value.

The electrohydrodynamic instability voltage varying is significant.

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