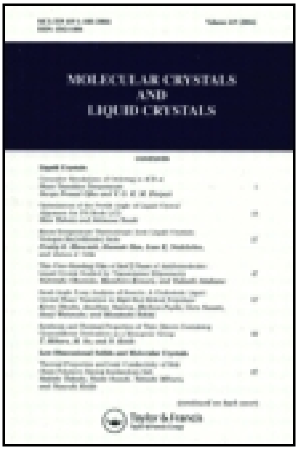

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Relaxation of Nematic Oriented by Magnetic and Electric Fields: Acoustical Investigation

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Relaxation of Nematic Oriented by Magnetic and Electric Fields: Acoustical Investigation

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We present the results of ultrasonic researches of bulk sample of nematic liquid crystal, oriented by joint action of electric and magnetic fields. The measurements were carried out in a nematic mixture with $\Delta\varepsilon>0$ previously oriented by a magnetic field. An electric field, applied to the LC sample induced the changes of a director orientation, and ultrasonic attenuation coefficient. The experimental dependencies are satisfactory described by the equation of motion of the director.

Keywords: electric field; magnetic field; nematic mixture

It is well known that ultrasonic method permits to investigate both fast and slow relaxation processes in liquid crystals. In the last case this process is connected with collective orientational motions of long molecular axes which can take place under the action of different factors (fields, shear flows and e.t.c.) In nematic phase this orientational relaxation can be described by the time-dependent angle changes between the liquid crystal director and the wave vector of ultrasound. It leads to the subsiquent variations of ultrasound attenuation ($\Delta\alpha(t)$) according to the expression:

$$\frac{\Delta\alpha}{f^2}(t)=\frac{\alpha(t)-\alpha(0)}{f^2}=a\{\cos^2[\Theta(t)]-\cos^2[\Theta(0)]\}+ \\ +b\{\cos^4[\Theta(t)]-\cos^4[\Theta(0)]\}, \quad (1)$$

where **f**-the ultrasonic frequency,

a and **b** - the parametres, proportional, to some combinations of the Leslie's coefficients,

The various ultrasonic experiments which were carried out both in nematic and smectic C [1] phases showed a rather high sensitivity of ultrasound to the orientational motions in relatively large liquid crystal samples, where the influence of the boundaries can be neglected. It permits to evaluate a lot of information about matherial coefficients of liquid crystals.

For example, the ultrasonic studies of nematic liquid crystals under rotating magnetic fields gave a possibility to measure the rotational viscosity coefficient at various temperature and pressure [2]. It is important to notice that such experiment is rather complicated namely one must provide a rotation of a magnet at different rates around the acoustic camera. Alternative type of ultrasonic experiments is realized in pulsing magnetic fields. But there are some problems in this case. Fistly, the propes time of arising magnetic field induction is rather long (2-5 s) for strong fields and must be taken into account under an explanation of experimental results. Secondly, the initial unoriented state of liquid crystal sample of large size looks like polydomain structure. So it is not clear if the classic hydrodynamics of nematics can describe the dynamical transformation from the polydomain state to the monodomain one. Obviously due to these problems there is only a qualitive agreement between the relaxation times obtained from the described above types of experiments.

To solve these problems one can try to rotate a monodomain liquid crystal sample from an initial position to a final one. It can be done without any mechanical motion by using an additional orientational factors, an electric field, for example. The results described in present paper show, that this way is very convinient for study an orientational relaxation in liquid crystals.

The main problem in using electric fields at an ulrtasonic investigation of volume samples of nematic liquid crystals is an achieving of a homogenioses field of high enough strength. Indeed typical values of a length of liquid crystal samples in the direction of ultrasound propagation (L) is about $(1..3)10^{-2}$ m. It leads to high electric voltages (more than 100V) which can effectivelly change an orientation even for liquid crystals with high values of anisotropy of electric permittivity ($\Delta\varepsilon \sim 10$). Moreover it is difficult to create a homogenious electric field localized in such large volumes, by applying an electric voltage directly to the surfaces of piezotransducers. So in our experiments, we used a number of plane acoustically transparent electrodes [3] to get a quiasi-homogenions electric field in the part of an investigated sample(see fig.1). A gap between the neighbour electrodes (d) equal to 1.1mm allowed to escape boundary influence in strong fields and to get field strength (E=27.3 kV/m) at electric voltage equal to 30V. A geometry of the experiment is presented in figure 2.

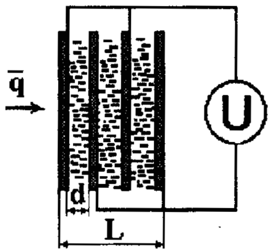

Fig.1.The circuit of submission of an electrical voltage on layers of a liquid crystal

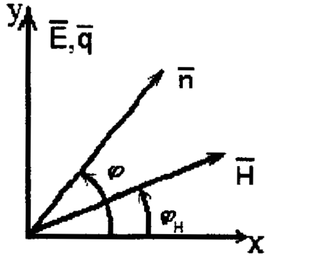

Fig.2.Geometry of the experiment

Firstly, the liquid crystal (nematic mixture LC-654 with $\Delta\varepsilon$=10,7) was oriented by the magnetic field of induction **B** at the angle (φ_H) relativelly to the wave vector **q**. When electric voltage is applied to the electrodes, the liguid crystal director **n** begins to move to the new equilibrium state, determined by a combined action of elecrtic and magnetic fields. The equation of this motion can be easy obtained neglecting elastic moments acting on the director:

$$\gamma_1 \frac{\partial\varphi}{\partial t} = a_H \sin 2\varphi_H(\cos^2\varphi - \sin^2\varphi) + 2(a_E - a_H \cos 2\varphi_H)\sin\varphi \quad (2)$$

,where $a_E=(\varepsilon_0\Delta\varepsilon E^2)/2$ и $a_H=(\mu^{-1}{}_0\Delta\chi H^2)/2$ – the parametres, which discribe the contributions of electrical and magnetic fields in reorientation of the director.

The solution of the equation (2) can be expressed as:

$$tg\varphi = \frac{\eta^2 - \cos 2\varphi_H}{\sin 2\varphi_H} + \frac{\left[tg\varphi_H - \frac{(\eta^2 - \cos 2\varphi_H)}{\sin 2\varphi_H}\right] + \left[1 + \left(\frac{\eta^2 - \cos 2\varphi_H}{\sin 2\varphi_H}\right)^2\right]^{\frac{1}{2}} th(\omega_{EH} t)}{1 + \left[1 + \left(\frac{\eta^2 - \cos 2\varphi_H}{\sin 2\varphi_H}\right)^2\right]^{-\frac{1}{2}} \left[tg\varphi_H - \left(\frac{\eta^2 - \cos 2\varphi_H}{\sin 2\varphi_H}\right)\right] th(\omega_{EH} t)} \quad (3)$$

where: $\omega_{EH} = \omega_H \sin 2\varphi_H \left[1 + \left(\frac{\eta^2 - \cos 2\varphi_H}{\sin 2\varphi_H}\right)^2\right]^{\frac{1}{2}}$ - a characteristic frequency of the director relaxation which takes place under a combined action of electric and magnetic fields.

$\omega_H = \frac{1}{2}\frac{\mu_0^{-1}\Delta\chi B^2}{\gamma_1}$ - a characteristic frequency of the director relaxation which takes place under an action of a magnetic field.

In these experiments the changes of $\Delta\alpha$ were measured by using an ultrasound of frequency 2 MHz passing through the twenty liquid crystal layers, devided by thin alluminium electrodes (20μ thickness). The time variations of an amplitude of transmitted ultrasound wave were registred with the help of a personal computer. To obtain the values of **a** and **b** the measurements were carried out at reorientation **B** relatively to **q**. The comparison between the experimental dependencies of $\Delta\alpha(t)$ and the theoretical calculation are show in figure 3.

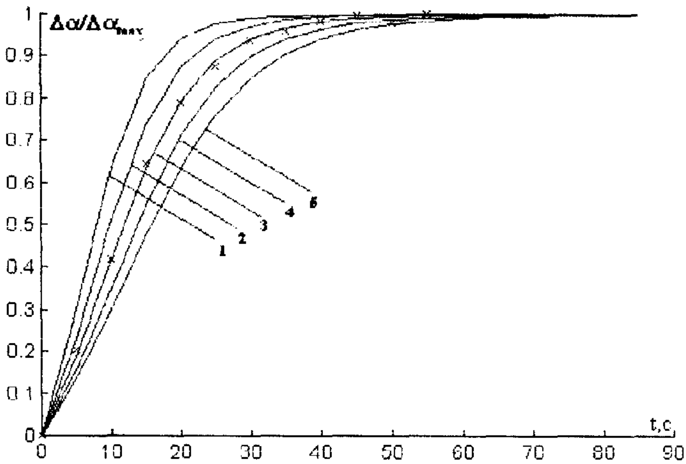

Fig. 3. Comparison a of experimental dates at B = 0.07T, $\varphi_H = 30^0$, U = 20V in with theoretically calculated ones (1-γ_1 = 0,3 kg $m^{-1}s^{-1}$, 2-0,32 kg $m^{-1}s^{-1}$, 3-0,34 kg $m^{-1}s^{-1}$, 4-0,36 kg $m^{-1}s^{-1}$, 5-0,38 kg $m^{-1}s^{-1}$).

The calculations were carried out at values of parametres a=2.2 $10^{-12} m^{-1} s^{2}$, b=0.64 $10^{-12} m^{-1} s^{2}$, $\frac{\gamma_1}{\Delta\chi}$ – 2.9 10^{-6} kg $m^{-1} s^{-1}$. The last value coincides with that obtained from well-known ultrasonic experiment in rotating magnetic field. The it approves the simple model of an orientational relaxation of nematic under combined action of electric and magnetic fields. So the experiment under considiration provides a correct determination of a rotational viscosity coefficient.

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