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# Acoustic study of reorientation in a smectic C phase in a rotating magnetic field

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# PRELIMINARY COMMUNICATION

# Acoustic study of reorientation in a smectic C phase in a rotating magnetic field

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The results of an ultrasonic study of a smectic C phase in a rotating magnetic field are presented. The observed dependence of the ultrasound absorption coefficient, $\alpha$, as a function of the angle, $\varphi_B$, of rotation of the magnetic field is discussed. It is shown that the temperature variation of the parameters, determining the dependence $\alpha(\varphi_B)$ can be explained within the framework of a simple model of the smectic C phase.

Compared with nematics, the study of the orientational structural changes of the smectic C phase and the action of a magnetic field seems to be more complicated and more interesting. The existence of the layer structure and thus the limitation of the displacement of the director leads to various possible reactions of the sample under the action of a magnetic field for different experimental geometries. We know of a few reported experimental studies [1, 2] of the influence of a magnetic field on the properties of the $S_C$ phase although often there is no comparison with theory.

Here we present the first results of an acoustic investigation of the $S_C$ phase in a rotating magnetic field. We have studied the *n*-hexyloxyphenyl ester of decyloxybenzoic acid having the phase sequence [3]

$$S_X \overset{317{\cdot}0\,\mathrm{K}}{\text{———}} S_C \overset{350{\cdot}6\,\mathrm{K}}{\text{———}} S_A \overset{356{\cdot}6\,\mathrm{K}}{\text{———}} N \overset{362{\cdot}1\,\mathrm{K}}{\text{———}} I$$

The $S_C$ phase was obtained by cooling it from the isotropic phase in a magnetic field of flux density $B_0$ of 0·5 T to 335 K. Then the magnetic field was turned off and the sample was placed in a rotating magnetic field of flux density $B$ of 0·3 T, so that the plane of rotation was normal to $\mathbf{B}_0$. The variation of the ultrasound absorption coefficient, $\alpha$, as a function of the rotation angle, $\varphi_B$, was determined in the experiment when the wavevector $\mathbf{q}$ and magnetic flux density $\mathbf{B}$ were in the same plane. The measurements at an ultrasonic frequency of 0·3 MHz were produced by the resonator method [4] at different temperatures and rotation frequency of the magnetic field, $\omega_B$.

The geometry of the experiment and a typical dependence $\alpha/f^2(\varphi_B)$ are shown in figures 1 and 2, respectively. The chosen geometry is perhaps one of the simplest, so that the experimental results can be explained rather easily. In this case the normal to the smectic layers coincides with $\mathbf{B}_0$ and the director $\mathbf{n}$ in the $S_C$ phase can move along the side of the cone, with the cone axis parallel to $\mathbf{B}_0$; the angle $2\psi$ depends on the temperature and becomes zero at the $S_C$–$S_A$ transition.

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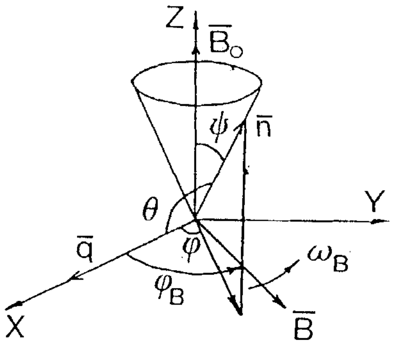

Figure 1. Geometry of the experiment.

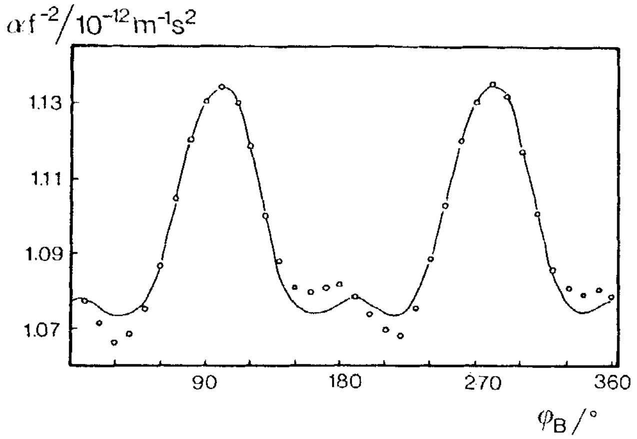

Figure 2. The dependence of $\alpha/f^2$ on $\varphi_B$. The result of approximating the experimental data (o) by equation (2) is shown as the solid line; $T = 349{\cdot}7$ K.

We think that the monodomain smectic C model is more suitable for our experimental situation than the polydomain model [1, 7]. In the compound under investigation the $S_C$ phase is formed from the $S_A$ phase, so that the tilt angle, $\psi$, in the region of the $S_A$–$S_C$ transition is small compared to $\psi$ of about 45° in the $S_C$ phase formed from the nematic, in which case the polydomain model evidently is appropriate. In our case, the layer structure obtained for the $S_C$ phase cannot differ in principal from the monodomain smectic A, especially near the $S_A$–$S_C$ transition. To destroy the monodomain structure of the $S_C$ phase a stronger field may be needed as used in the studies [1, 7] where $B_0$ is about 1·4 T. In our experiment the magnetic flux density was relatively small (0·5 T) and so we believe that it does not destroy the layer structure. This conclusion is also confirmed by the results of the ultrasonic study in the vicinity of the $S_A$–$S_C$ transition, which will be published later.

Rotation of a comparatively weak magnetic field (0·3 T) also does not change the layer structure, so we can suggest, that the variation of $\alpha$ when the magnetic field is rotated is due to alterations of the angle $\theta$ between **q** and **n** in much the same way as for nematics [5]. As shown in figure 1

$$\cos\theta = \sin\psi\cos\varphi. \qquad (1)$$

Thus, at a fixed temperature the variations of $\alpha$ are due to the corresponding variations of $\varphi$; note, that $\varphi \rightarrow \varphi_B$, when $\omega_B \rightarrow 0$. Assuming the behaviour of the projection of the director on to the smectic layer to be quasinematic, we have attempted to treat the dependence $\alpha(\varphi_B)$ obtained using the expression found for nematics [5]

$$\alpha/f^2 = a\cos^2(\varphi_B - \tilde{\varphi}) + b\cos^4(\varphi_B - \tilde{\varphi}) + c, \qquad (2)$$

where $\tilde{\varphi}$, in the case of a nematic, is the delay angle between **B** and **n**. The result of such fitting with the least square method is shown in figure 2 by a solid line. Note, that this expression describes qualitatively the principal peculiarities of the experimental dependence, namely, the shape of the curve and the existence of the two additional extrema at $\varphi_B$ not equal to 0 or 90°. However, different values of these extrema cannot be explained by equation (2) and an additional approach is needed.

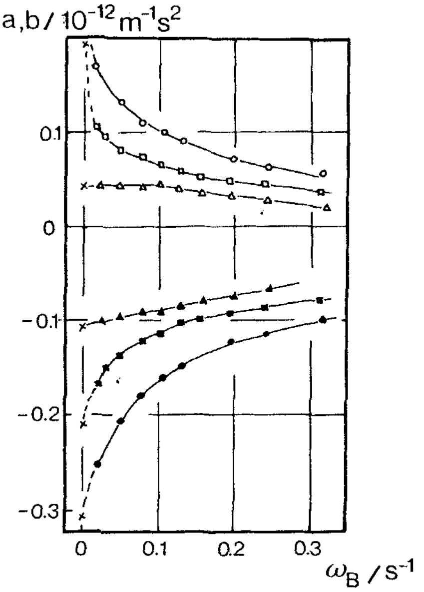

Figure 3. The dependence of the parameters $a$ and $b$ on the angular velocity of the magnetic field; ●, ■, ▲, $a$; ○, □, △, $b$; ○, ●, $T$ = 335·1 K, □, ■, $T$ = 342·7 K; △, ▲ $T$ = 347·6 K.

The dependence of the coefficients $a$ and $b$ on $\omega_B$ at different temperatures is shown in figure 3. Note that, unlike the nematics, the coefficients $a$ and $b$ do depend on $\omega_B$ beginning with small values of the rotational velocity. This is important, when discussing the experimental results, especially for the region far from the $T_{S_CS_A}$. Figure 4 shows the experimental temperature dependence of the coefficients $a$ and $b$, obtained at the minimum experimental value of $\omega_B$ namely 0·02 s$^{-1}$. The behaviour of $a(T)$ and $b(T)$ can be explained within the framework of the suggested approach. Indeed it follows from equation (1) that $a \approx \sin^2\psi$, $b \approx \sin^4\psi$. Taking into account that $\psi$ is the modulus of the order parameter for the S$_C$ phase and depends on the temperature as $\psi \sim (\Delta T)^\beta$ [6], for small values of $\psi$ we have

$$a \sim (\Delta T)^{2\beta}, \quad b \approx (\Delta T)^{4\beta}. \qquad (3)$$

The dependence in equation (3) for $\beta$ = 0·25 is shown in figure 4 by the solid lines. The experimental temperature dependence of $a(T)$ and $b(T)$ in the region

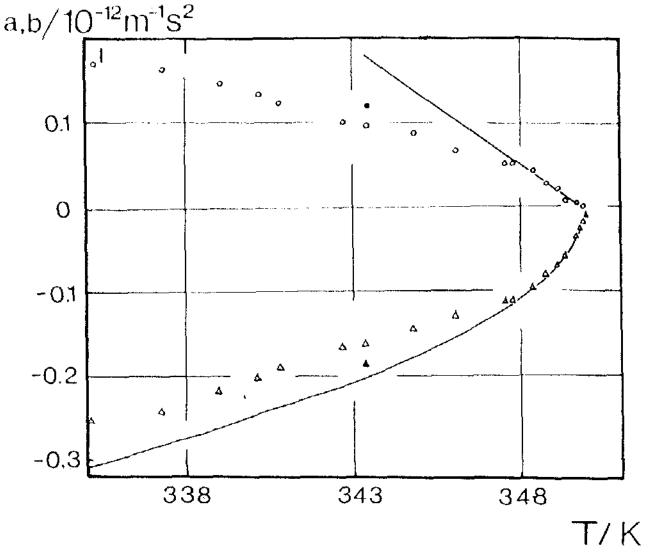

Figure 4. The temperature dependence of $a$ and $b$ at $\omega_B$ of 0·02 s$^{-1}$ (◇, △) and $\omega_B$ of 0·005 s$^{-1}$ (●, ▲). The dependence predicted by equation (3) with $\beta = 0·25$ is shown as the solid line.

$(T_{S_CS_A}-T) \lesssim 2$ K have a satisfactory description within the framework of this approach. The deviation of the experimental values of $a$ and $b$ from the power laws (3) in the region far from $T_{S_CS_A}$ can be explained by the fact that for this temperature region the velocity of rotation $\omega_B = 0·02\,s^{-1}$ cannot be considered to be small, as noted previously (see figure 3). For comparison in figure 4 we show the values of $a$ and $b$ obtained at 343·4 K and $\omega_B = 0·005\,s^{-1}$ which are in better agreement with the approximate values. However, even this small velocity of rotation of the magnetic field obviously does not correspond to the limiting value when $\omega_B \to 0$. This is also confirmed by the fact that the coefficients $a$ and $b$ calculated using equation (3) and shown in figure 4 (as a solid line) are in accord with the dependence $a(\omega_B)$ and $b(\omega_B)$. The small difference between the experimental (0·25), theoretical (0·33) values of $\beta$ and those found for TBBA in [1, 7] is not surprising taking into account the simplicity of the approach used. In particular, the value of $B$ used in the experiment is probably not enough for orientation of the director in the single direction on the side of the cone. The influence of possible defects of the layer structure on the experimental results is also not clear. We hope that the investigation we are now carrying out will give the answer to these questions.

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