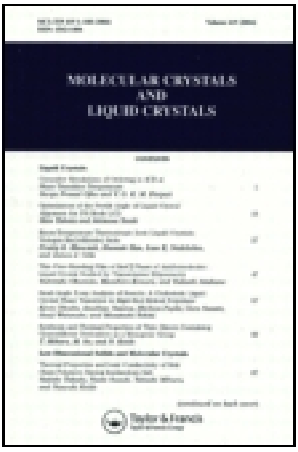

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Investigation of the Smectic C* - Smectic A Phase Transition in Electric Field

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INVESTIGATION OF THE SMECTIC C* - SMECTIC A PHASE TRANSITION IN ELECTRIC FIELD

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Abstract A sharp maximum of the soft mode strength has been observed at the chiral smectic C* - smectic A phase transition using an optical detection method. The soft mode peak has been used as an indicator of the phase transition in the absence of external electric field. Electric field broadens the maximum and shifts it towards higher temperatures. Analysis of the soft mode critical behaviour shows that the dc field does not affect the phase transition temperature.

INTRODUCTION

The SmC*-SmA phase transition in chiral liquid crystals represents the transition from ferroelectric to paraelectric phase. It is one of the most frequently studied phase transitions in liquid crystals. The exact determination of the phase transition temperature is especially important here, however in some cases it makes serious difficulties. For example, in dielectric studies the transition is usually undetectable and therefore these studies are frequently accompanied with microscope observations. The temperature at which the stripes characteristic of the SmC* helical phase appear is often recognized as the transition temperature. However, the stripes of helical structure appear usually at temperature slightly lower than that of the tilt, which is the proper criterion of the phase transition. Thus, it would be convenient to have a distinct, universal indicator of the SmC*-SmA transition temperature. In this paper we show that the soft ferroelectric mode, i.e. vibrations related to the tilt angle, can be used as such indicator. To determine the temperature of transition from ferroelectric to paraelectric phase one can make use of the fact that amplitude and relaxation time of the soft mode have maximum values at this point. Here, we will show that the amplitude maximum can be easily detected with optical methods.

EXPERIMENTAL

To observe the ferroelectric modes we applied optical method which consists in measurement of the ac electric field-induced modulation of light transmitted through a sample. Two different orientations of samples were used: planar (smectic layers perpendicular to glass plates) and homeotropic (smectic layers parallel to glass plates). In both cases the applied electric field was parallel to the smectic layers. The details concerning the measurement procedure will be described in separate paper[1]. Here, we stress only that the optical method used by us provides the results analogous to these which can be obtained with the dielectric method. Considerably higher sensitivity of this optical method in respect to dielectric measurements is its useful advantage. The measurements were performed for 4-octyloxy 4- [(2-methyl- butyloxy)carbonyl] phenylbenzoate with the following phase transition scheme:

$$\mathrm{Cr}\ 32\ (S_C^*\ 30.5)\ S_A\ 55\ \mathrm{Iso.}$$

RESULTS AND DISCUSSION

Temperature dependence of the light modulation amplitude is given in Fig.1. It shows, that besides the relatively broad maximum (≅0.5°C) assigned to the Goldstone mode which is located slightly below the phase transition[2], one observes an additional, narrow (≅0.02C°) local maximum. The microscope observations revealed that this maximum occurs exactly at the SmC*-SmA phase transition temperature. The existence of such a peak was predicted by Levstik et al.[3] as a manifestation of the soft mode, which has a maximum strength at this point. Since the observed peak is exceptionally nar-

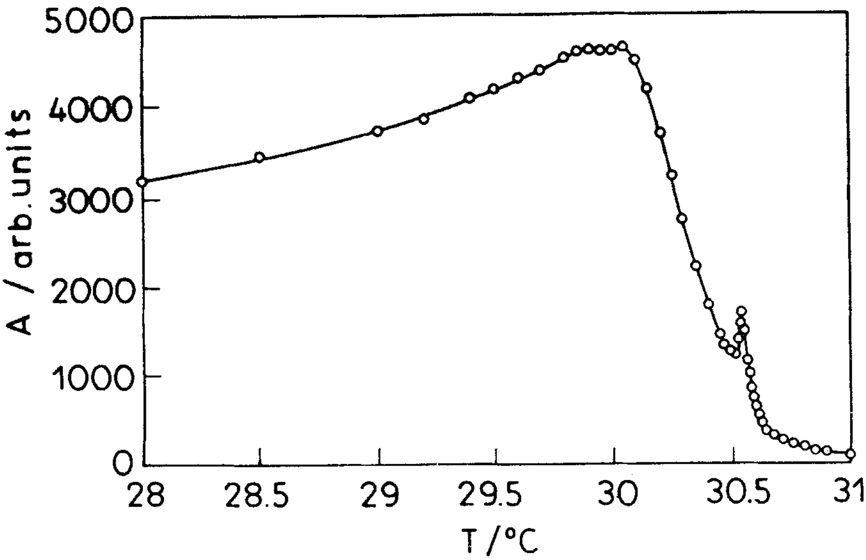

FIGURE 1. Light modulation amplitude as a function of temperature in the vicinity of the SmC*-SmA phase transition. Measuring field 500 V/m, frequency 30 Hz, sample thickness 120 μm, homeotropic orientation.

row it can be used as a convenient and precise indicator of the phase transition point while studying the effects of various factors on the SmC* - SmA phase transition. Fig.2 shows changes in shape of this peak caused by a dc electric field applied parallel to the measuring ac field (in the plane of smectic layers). The bias electric field causes a decrease in the maximum amplitude of the soft mode and shifts it towards higher temperatures. Simultaneously, the Goldstone mode, which is active below the transition, undergoes even a stronger suppression. In agreement with the theoretical predictions[4] the temperature of the maximum is shifted proportionally to $E_{bias}^{2/3}$. A question arises, whether the shift of temperature of the soft mode maximum is equivalent to the shift of the phase transition. The answer is given in Fig.3, in which the reciprocals of the light modulation amplitude are plotted as a function of temperature.

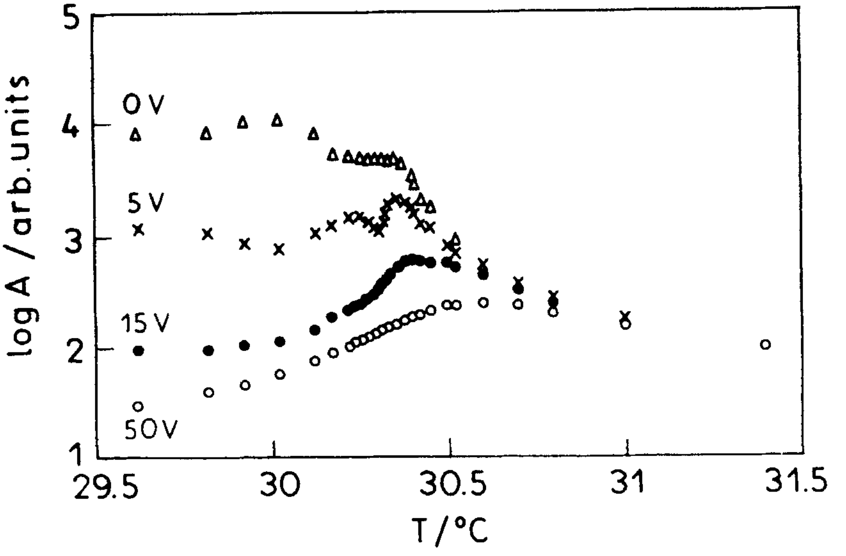

FIGURE 2. Optical response as a function of temperature for various values of the biasing voltage. Thickness of sample 30 μm, planar orientation.

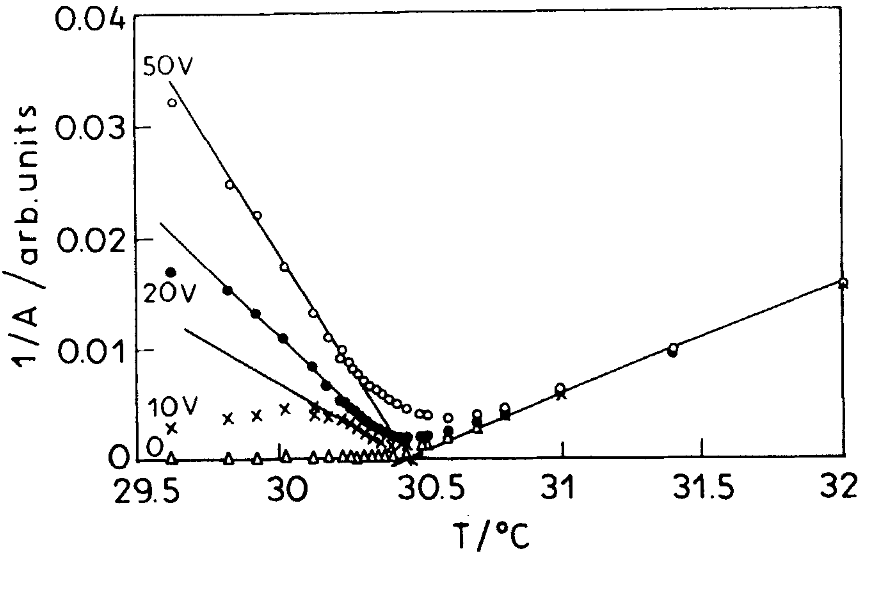

FIGURE 3. Reciprocals of the modulation amplitude as a function of temperature for various values of the bias voltage.

Rectilinear sections of the dependences shown in Fig.3 indicate that within a certain temperature range the Curie Weiss law $A = C/(T-T^*)$ is fulfilled in both paraelectric and ferroelectric phase. The critical temperature T^* extrapolated from both sides of the SmC*-SmA transition equals to the temperature of the phase transition (within an accuracy of the measurement). The critical temperature is independent of the electric field strength. In the presence of an external electric field this temperature is also the same as the phase transition temperature T_{CA}. Thus, in agreement with the theoretical prediction[5] the SmC*-SmA transition is not shifted but only blurred under the influence of electric field. The shift of the soft mode maximum is caused by its different suppression at both sides of the phase transition.

CONCLUSIONS

A sharp maximum of the soft mode strength being a convenient indicator of the SmC*-SmA transition has been found. Electric field shifts this maximum towards higher temperatures. However, it does not mean that the SmC*-SmA transition temperature also undergoes shifting. In presence of the bias field this transition blurs, but the critical temperature determined from the Curie-Weiss law on both sides of the transition is independent of field strength.

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