

## DETERMINATION OF THE SmA – SmC\* PHASE TRANSITION IN DOBAMBC AND ITS DIELECTRIC RELAXATION

A. Levstik, T. Carlsson\*, C. Filipič, and B. Žekš  
J. Stefan Institute, E. Kardelj University of Ljubljana,  
61000 Ljubljana, Yugoslavia

\* Institute of Theoretical Physics, Chalmers University  
of Technology, S – 41296 Goteborg, Sweden

### Abstract:

*The complex dielectric constant as a function of temperature and frequency has been measured in DOBAMBC close to the SmA – SmC\* phase transition. The relaxation frequency and the dielectric strength of the Goldstone mode and soft mode were determined and the results are compared with the dielectric strength calculated using an extended Landau type of freeenergy density proposed by Žekš. By analysing the experimental data carefully we are able to establish the SmA – SmC\* phase transition temperature to be located a few degrees above the comparatively „broad“ maximum exhibited by the dielectric strength. This location is also supported by our theoretical model.*

A considerable experimental and theoretical progress has been made in understanding the SmA – SmC\* phase transition since 1975 when existence of ferroelectric liquid crystals was reported by Meyer et al<sup>1</sup>. The dielectric constant is one of many studied properties<sup>2 – 7</sup> but still exists important disparity between different authors in the location of the maximum of the low frequency dielectric constant and the SmA – SmC\* phase transition temperature. Some authors report  $T_C^{5,6}$  to be at the temperature of the maximum of the low frequency dielectric constant (we denote this temperature by  $T_O$ ). These authors have in general not determined  $T_C$  by any independent method but just assumed  $T_C$  to coincide with  $T_O$ . Other authors<sup>2 – 4, 7</sup> have located  $T_C$  few degrees above this maximum. This is, in our opinion, the correct assignment of  $T_C$  what we will show in this work by analysing dielectric relaxation measurements.

The frequency and temperature dependence of the complex dielectric constant has been measured in the ferroelectric liquid crystal DOBAMBC in the frequency range from 20 Hz to 4 kHz close to the SmA – SmC\* phase transition. The measured data were analysed by the use of Cole-Cole plots. The details of this analysis in the case of ferroelectric liquid crystals are discussed elsewhere<sup>7</sup> and also the results of the measurements have partly been published previously<sup>3</sup>.

Generally two modes are expected to contribute to the dielectric strength of ferroelectric liquid crystals. One of those is connected to the phase changes (Goldstone mode) while the other is connected to the amplitude changes (soft mode) of the order parameters. We have resolved the measured dielectric strength into the contribution from these two modes.

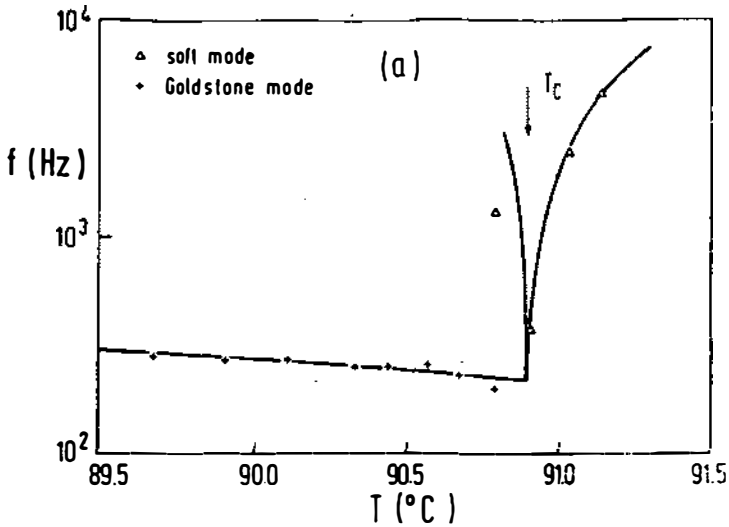


Fig. 1a. The dielectric dispersion frequency of DOBAMBC as a function of temperature.

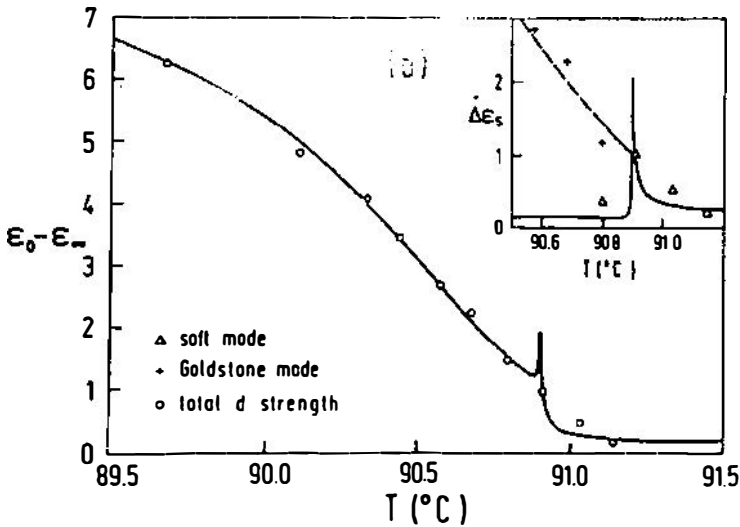


Fig. 1b. The dielectric strength  $\epsilon_0 - \epsilon_{\infty}$  of DOBAMBC as a function of temperature (circles), the full line represents calculated results. The inset shows the separation of the dielectric strength into the Goldstone mode (crosses) and the soft mode (triangles). The full line represents the calculated contribution of the soft mode while the dotted line represents the calculated contribution of the Goldstone mode.

In Fig. 1a the relaxation frequencies of the Goldstone mode (crosses) and of the soft mode (triangles) are shown as a function of temperature. The cusp-like minimum of the relaxation frequency of the soft mode enables us to determine  $T_C$ . For  $T > T_C$  the solid line through the experimental points is given by the expression  $f_s = k(T - T_C)$  where we have determined  $k$  to be 17.6 kHz K<sup>-1</sup>. For  $T < T_C$  we have plotted the line  $f_s = 2k(T_C - T)$ . This is motivated by the fact that in solid ferroelectrics the behaviour of the soft mode is generally such, that the slope of the  $f_s(T)$  line is twice as large in the low symmetry phase 8. The solid line through the points of the Goldstone mode serves just as a guide to the eye.

In Fig. 1b the circles show the obtained dielectric strength  $\epsilon_0 - \epsilon_\infty$  as a function of temperature. It is related to the susceptibility  $\chi$  by the relation  $\chi = \epsilon_s(\epsilon_0 - \epsilon_\infty)$ , where  $\epsilon_s$  is the permittivity of free space. The solid line through the circles shows the result of a model calculation<sup>8</sup> of obtained by the best fit through the measured values using the parameters  $\gamma = 1.84$ ,  $\beta = 0.28$ ,  $\rho = 2.0$ ,  $\lambda = 0.091$ ,  $\tau = -0.01$ ,  $\delta = 2.6 \times 10^{-3}$ . As the calculations are performed by writing the equations in dimensionless form, we also determine the corresponding scaling factors: 0.50 K for the temperature scale and  $1.59 \times 10^{-12}$  C/Vm concerning the scale of the dielectric susceptibility. For the definition of these parameters and scaling factors the reader is referred to the references 7.

The results of this analysis can be summarized as follows:

1. Both relaxation frequency and the dielectric strength of the Goldstone mode, as well as the total dielectric strength, are smooth and continuous functions of temperature at  $T_C$ . Generally, we would expect some kind of discontinuity of the derivative of this quantities at a second order phase transition.

2. At the temperature to which we assign the phase transition the dielectric strength of the Goldstone mode ceases to exist, while the dielectric strength of the soft mode exhibits a peak. Also the relaxation frequency of the soft mode exhibits a cusp-like minimum at this temperature as can be seen in Fig. 1a. This fulfils the requirement of a discontinuous behaviour of the dielectric properties at  $T_C$  which was demanded above.

3. By the simultaneous measurements at the low frequency dielectric constant and the pitch of the helix of a ferroelectric liquid crystal mixture<sup>9</sup>, we have confirmed our choice of  $T_C$  to be the correct one.

## REFERENCES

1. R. B. Meyer, L. Liebert, L. Strzelecki and P. Keller, *J. Physique Lett.* **36**, L69 (1975)
2. K. Yoshino, T. Uemato and Y. Inuishi, *Jap. J. Appl. Phys.* **16**, 571 (1977)
3. A. Levstik, B. Žekš, I. Levstik, R. Blinc and C. Filipič, *J. Physique C3*, **40**, 303 (1979)
4. M. Glogarova and J. Pavel, *Mol. Cry. Liq. Cryst.* **114**, 249 (1984)
5. J. Hoffman, W. Kuczynski and J. Malecki, *Mol. Cryst. Liq. Cryst.* **44**, 287 (1978)
6. B. I. Ostrowski, A. Z. Rabinowich, A. S. Sonin and B. A. Strukov, *Zh. Eksp. Teor. Fiz.* **74**, 1748 (1978)
7. A. Levstik, T. Carlsson, C. Filipič, I. Levstik and B. Žekš, submitted to *Phys. Rev. A*.
8. R. Blinc, and B. Žekš, *Soft Modes in Ferroelectrics and Anti-ferroelectrics*, North-Holland (Amsterdam 1974)
9. A. Levstik, B. Žekš, C. Filipič, R. Blinc and I. Levstik, *Ferroelectrics* **58**, 33 (1984)