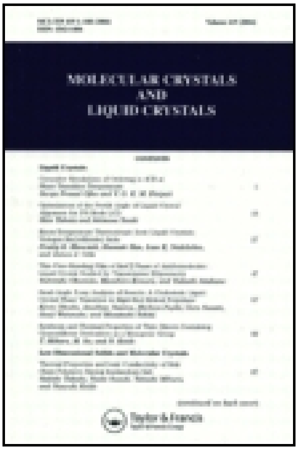

Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gmcl19

Resonance Phenomena in a Ferroelectric Liquid Crystal Near the Phase Transition SmA - SmC*

Mikhail Pivnenko [a] , Alexandr Fedoryako [a] , Lidiya Kutulya [a] & Vladimir Seminozhenko [a]

[a] Institute for Single Crystals, 60 Lenin Ave., Kharkov, 310001, Ukraine E-mail:

To cite this article: Mikhail Pivnenko, Alexandr Fedoryako, Lidiya Kutulya & Vladimir Seminozhenko (1999): Resonance Phenomena in a Ferroelectric Liquid Crystal Near the Phase Transition SmA - SmC*, Molecular Crystals and Liquid Crystals Science and Technology. Section A. Molecular Crystals and Liquid Crystals, 328:1, 111-118

To link to this article: http://dx.doi.org/10.1080/10587259908026051

Mol. Cryst. Liq. Cryst., 1999, Vol. 328, pp. 111-118
Reprints available directly from the publisher
Photocopying permitted by license only

Published by license under the
Gordon and Breach Science Publishers imprint.
Printed in Malaysia

Resonance Phenomena in a Ferroelectric Liquid Crystal Near the Phase Transition SmA – SmC*

MIKHAIL PIVNENKO, ALEXANDR FEDORYAKO,
LIDIYA KUTULYA and VLADIMIR SEMINOZHENKO

Institute for Single Crystals, 60 Lenin Ave., Kharkov 310001, Ukraine. E-mail: pivnenko@isc.kharkov.com

Dynamic properties of ferroelectric liquid crystals have been studied by means of observation of electric, optical and mechanical responses to the step-like change of electric field strength. A resonance low-frequency mode interpreted as a texture one has been revealed near the phase transition SmA – SmC*. Interaction between this texture resonance mode and bending modes of glass cell plates and the synchronization effect have been found. Temperature and electric field dependences of the texture resonance mode parameters are given.

Keywords: ferroelectric liquid crystals; resonance low-frequency mode

INTRODUCTION

Low-frequency dynamic properties of ferroelectric liquid crystals (FLC) have been described by means of the Goldstone mode, the soft mode and a number of another modes [1]. Due to the absence of elastic reverse strength, all these processes have relaxation nature but non-resonance one, and an external force simply causes a flow. However, for smectic liquid crystals (provided that the external force is applied in the direction perpendicular to smectic layers) as well as for liquid crystalline elastomers the reverse strength arises that results in a piezoelectric voltage [2-5]. It can be assumed that this reverse elastic strength makes fluctuations be reversible ones and the response to an external influence becomes a resonance one. In this work, we present experimental results of investigations into low molar mass FLC when they show a resonance response to a step-like change of the electric field strength.

EXPERIMENTAL

Experiments were performed on a two-component mixture containing a smectogenic matrix and a chiral dopant (CD). A smectic C, namely 2-(4-octylhydroxyphenyl)-5-octylpyrimidine (**1**), was selected as the matrix. Bis-4,4'-(2-S-methylpentyl)terphenyldicarboxylate (**2**) or bis-4,4''-(2S-2-chlorohexyl)-terphenyldicarboxylate (**3**) [6] were used as chiral dopants allowing to obtain a sufficiently high spontaneous polarization. Mixtures on the base of **1** including 19.7 wt % of CD **2** or 25.7 wt % of CD **3** show the second-order phase transition SmA — SmC* at 60°C and 65°C, respectively.

The FLC layer was placed between parallel glasses with transparent SnO_2 electrodes coated with lecithin to get homeotropic aligment. The layer thickness d amounted from 5 to 20 μm and was set by spacers. One of the glasses was fixed on a thermostating device while the other laid freely on the FLC layer. The uniform bookshelf texture was obtained by transforming from the homeotropic texture in the SmC* phase using electric field and shear. Details of the alignment procedure were similar to those described before [7,8].

Square electric pulses of alternative polarity and of 10 ms duration were applied to the cell electrodes causing the field strength up to $E = 5$ V/μm in the FLC layer. The repolarization current value was measured. Mechanical vibrations in the movable cell glass were detected by a piezosensor. To observe the optical response, the sample was placed between crossed polarizers and illuminated by a low-power He-Ne laser beam (632.8 nm).

RESULTS AND DISCUSSION

Free damping mechanical vibrations of the sample cell plates arising under fast field reversal [8–10] are accompanied by oscillations of the induced polarization current [11] and optical transmission oscillations of the sample placed between crossed polarizers [12]. A high correlation between frequencies, phases and damping decrements of electric, optical and mechanical vibrations in the direction parallel to the cell plates and perpendicular to the smectic layers have been revealed [8,12] that confirms the existence of collective director oscillations. Fig. 1 presents the induced polarization current oscillations under fast field reversal both in SmC* and SmA phases.

The spectrum of the collective director oscillations is discrete and lies in the range from 1 to 100 kHz. Two different types of resonances were discerned therein [11,13]. The first one is bending modes of the cell glass plates. Frequencies of these resonances do not depend on external parameters (temperature, electric field strength) [9,13]. The second type resonance shows a continuous dependence of all parameters on temperature [12,14], electric field strength [13] and mechanical stress [15], thus allowing us to suppose that this resonance is a texture one.

Fig. 2 illustrates the process of interaction between the texture resonance and the bending modes of the plates. Different bending modes are excited by oscillations at texture resonance depending on temperature or electric field strength; in other words, the texture resonance is synchronized with the nearest bending mode. Oscillations on the texture mode are excited immediately after the field is reversed, since the excitation time of that mode is small due to its relatively low quality. 1 – 1.5 ms later, oscillations on the nearest bending mode are excited due to interactions of these modes.

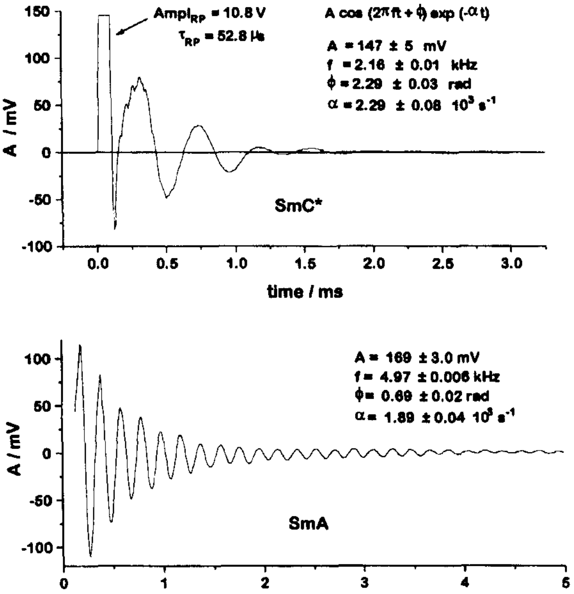

FIGURE 1 Electrical oscillations at the temperature 64°C (SmC*, d = 7 μm, E = 2.85 V/μm) and 65.5°C (SmA, d = 15 μm, E = 3 V/μm) CD 3 25.7 wt %.

Typical temperature and electric field dependences of the main oscillation parameters for the texture resonance are shown in Fig. 3 and Fig. 4, respectively, for the mixture including 25.7 wt % of CD 3. The oscillations were found to be of the highest intensity at 65°C (being the temperature of the SmA — SmC* phase transition). As the temperature is reduced to the phase transition point from the SmA side, the oscillation frequency decreases and its temperature dependence is similar to that of the sound speed in the FLC.

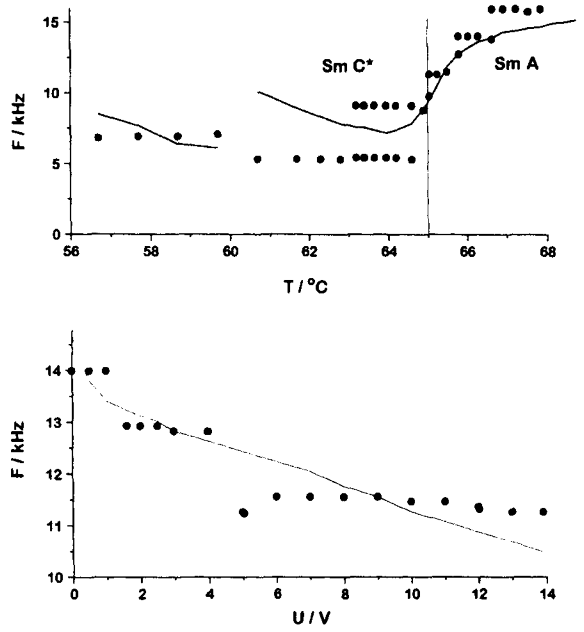

FIGURE 2 Temperature and electric field dependences of oscillation frequency for the texture resonance (solid line) and bending modes of plates (•).

The oscillation amplitude grows according to an exponential law $A \sim [T_c/(T-T_c)]^{\gamma}$. This fact suggests that the oscillations are caused mainly by the electroclinic effect. However, a high value of the exponent $\gamma = 3 \pm 0.5$ indicates that these oscillations are not defined by the electroclinic effect only. On the SmC* side, the oscillation frequency is temperature-independent and is equal to the lowest value attained at the phase transition point. The oscillation spectrum is shifted towards low frequencies when the cell thickness is diminished.

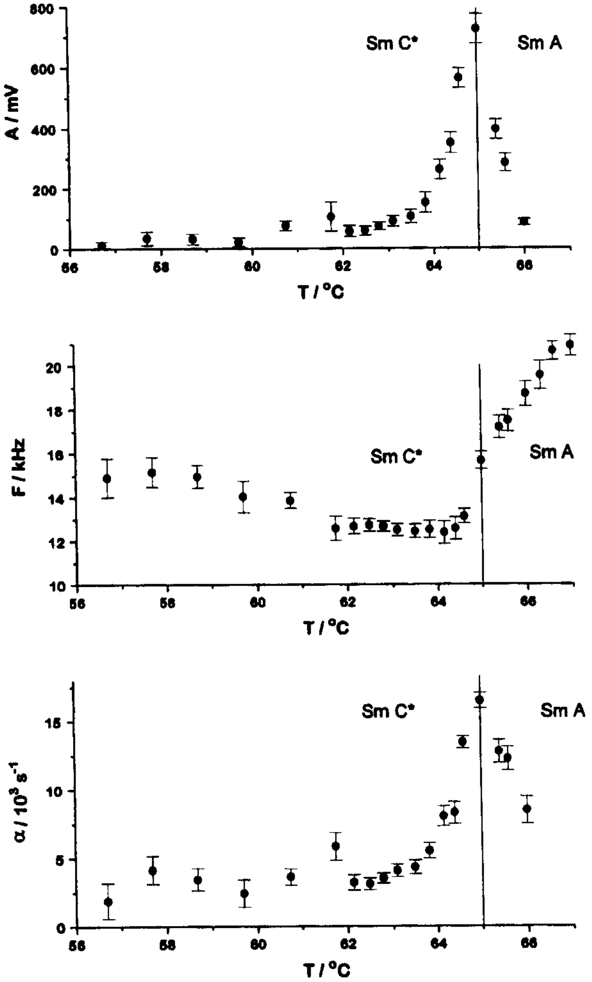

FIGURE 3 Temperature dependences of amplitude (A), frequency (F) and damping decrement (α) of oscillations for the texture resonance (d = 15 μm, E = 1 V/ μm).

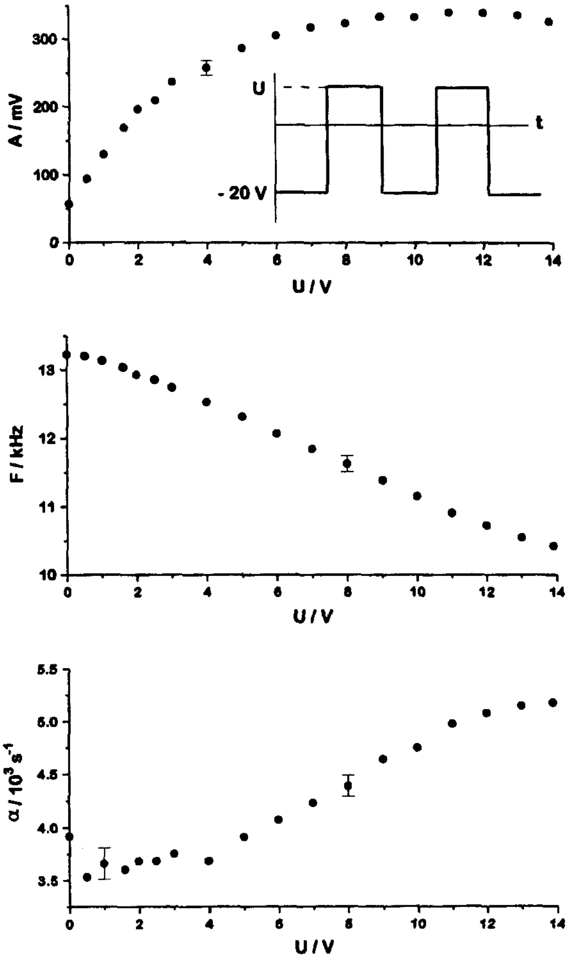

FIGURE 4 Electric field dependences of amplitude (A), frequency (F) and damping decrement (α) of oscillations for the texture resonance (d = 15 μm, T = 64°C).

CONCLUSION

Low molar mass FLC show a resonance response to an external altemant electric field. This response consists of a texture mode and bending modes of the cell plates. Interaction between the texture mode and the bending modes have been illustrated.

Acknowledgments

The authors acknowledge the support received from the Organizing Committee of 16th ILCC, Kent, USA.

References

[1] See, for example, M. Glogarova, V. Novotna, H. Sverenyak, A. Bubnov, *SPIE,* **3318,** 39 (1998) and references therein.

[2] S. Garoff and R. Meyer, *Phys. Rev. Lett.,* **38,** 848 (1977).

[3] S.U. Vallerien, F. Kremer, E.W. Fischer, H. Kapitza, R. Zentel, H. Poths, *Makromol. Chem., Rapid Commun.,* **11,** 593 (1990).

[4] E.M. Terentjev and M. Warner, *J. de Physique II,* **4,** 111 (1994).

[5] T. Eckert, H. Finkelmann, M. Keck, W. Lehmann, and F. Kremer, *Macromol. Rapid Commun., 17,* 767 (1996).

[6] M. Loseva, N. Chernova, A. Rabinovich, et al., *Ferroelectrics,* **114,** 357 (1991).

[7] A. Jákli and A. Saupe, *Appl. Phys. Lett.,* **60** (21), 2622 (1992).

[8] A.P. Fedoryako, M.N. Pivnenko, E.V. Popova, and V.P. Seminozhenko, *Functional Materials,* **4,** 375 (1997).

[9] A. Jákli and A. Saupe, *Mol. Cryst. Liq. Cryst.,* **263,** 103 (1995).

[10] A. Jákli, *Mol. Cryst. Liq. Cryst.,* **292,** 293 (1997).

[11] A.P. Fedoryako, M.N. Pivnenko, E.V. Popova, and V.P. Seminozhenko, *Technical Phys. Lett.,* **23** (4), 287 (1997).

[12] M.N. Pivnenko, A.P. Fedoryako, E.V. Popova, and L.A. Kutulya, *SPIE,* **3488,** 28 (1998).

[13] M.N. Pivnenko, A.P. Fedoryako, and V.P. Seminozhenko, *Ukrainian Journal of Physics,* **42,** 1314 (1997) [In Ukrainian].

[14] A.P. Fedoryako, M.N. Pivnenko and E.V. Popova, *SPIE,* **3318,** 110 (1998).

[15] M.N. Pivnenko, A.P. Fedoryako, and V.P. Seminozhenko, *Proc. of 17th Inter. Liq. Cryst. Conf.,* Strasbourg, France, 1998.