

RELAXATION OF THE DIELECTRIC CONSTANT AND ELECTROHYDRODYNAMIC INSTABILITIES IN A LIQUID CRYSTAL

W. H. De JEU, C. J. GERRITSMA, P. Van ZANTEN and W. J. A. GOOSSENS

Philips Research Laboratories, Eindhoven, The Netherlands

Received 4 May 1972

Electrohydrodynamic instabilities are studied in a liquid crystal in which the dielectric anisotropy $\Delta\epsilon$ changes sign because of a relaxation of ϵ_{\parallel} . Above the frequency where $\Delta\epsilon = 0$ a new conduction regime is found.

In a nematic liquid crystal the relaxation of ϵ_{\parallel} often occurs in the MHz region, where ϵ_{\perp} still remains constant [1-3]. For nematics with $\Delta\epsilon = \epsilon_{\parallel} - \epsilon_{\perp} < 0$ this leads to an increase of $|\Delta\epsilon|$ whereas for nematics with $\Delta\epsilon > 0$ this may lead to a change of sign of $\Delta\epsilon$. In fig. 1 we give the dielectric constants of WI (E. Merck [4]), a room temperature mixture of four nematic compounds with a carboxylic acid ester bridging group. At 25°C $\Delta\epsilon$ changes sign at $f_0 = 10$ kHz. Recently, a similar behaviour has been reported for some Schiff bases [5].

The instabilities of a planar nematic layer in electric fields have been studied extensively for compounds with negative $\Delta\epsilon$ [6] (Williams domains and at higher voltages turbulence and dynamic scattering),

and positive $\Delta\epsilon$ [7, 8] (reorientation). The change of sign of $\Delta\epsilon$ of WI gives the opportunity to check these results within the same sample, especially with regard to the type and origin of the instabilities.

The threshold voltage for instability in WI has been determined as a function of the frequency using the method described in [8]. The results are given in fig. 2. At low frequencies the instability takes the form of a reorientation while loop domains are observed as a transient effect (just as in p-p'-di-n-butylazoxybenzene [8]). However, above f_0 stable domains are observed and, on increasing the voltage, turbulence and dynamic scattering; this conduction regime extends from 10 to 12 kHz. Above the latter critical frequency f_c chevrons are observed. This regime is preceded by

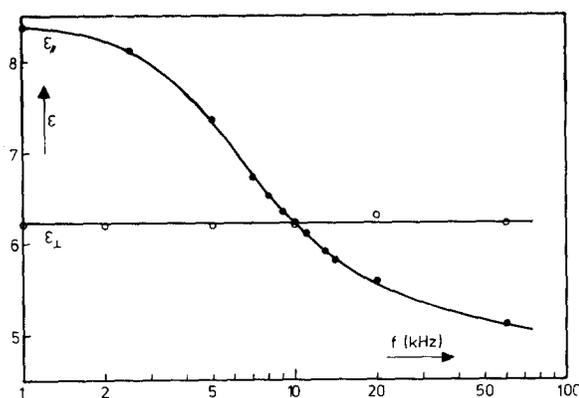


Fig. 1. Dielectric constants of WI at 25°C.

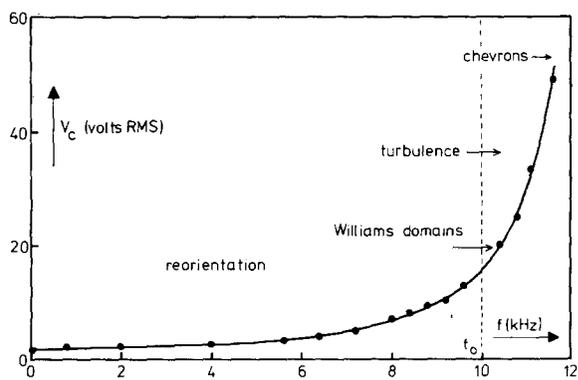


Fig. 2. Threshold voltage for instability of a planar 50 μm WI layer at 25°C ($\sigma \approx 10^{-9} \Omega^{-1} \text{cm}^{-1}$).

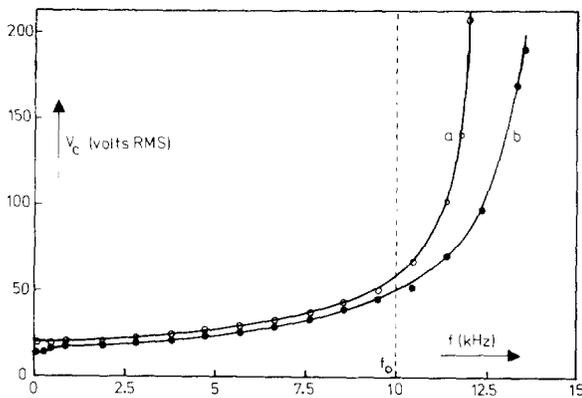


Fig. 3. Threshold voltage for instability of a planar $50 \mu\text{m}$ cholesteric WI layer (pitch = $3 \mu\text{m}$) at 25°C . (a) $\sigma \approx 10^{-9} \Omega^{-1} \text{cm}^{-1}$; (b) $\sigma \approx 2 \times 10^{-9} \Omega^{-1} \text{cm}^{-1}$.

a region (8–10 kHz) where stable domains are also observed at the threshold voltage. However, on increasing the voltage these domains change into loop domains and disappear, leaving only the effect of a reorientation.

If for $\Delta\epsilon > 0$ the instability were a pure dielectric effect one would expect $V_c \rightarrow \infty$ for $f \rightarrow f_0$. The fact that there is no anomaly in the threshold voltage at f_0 , where $\Delta\epsilon = 0$, is conclusive evidence that the instability is mainly of hydrodynamic origin both for $\Delta\epsilon > 0$ and $\Delta\epsilon < 0$ [8].

Electrohydrodynamic instabilities in planar cholesteric textures, leading to periodic grid-like patterns have recently been reported for cholesteric mixtures with both $\Delta\epsilon > 0$ and $\Delta\epsilon < 0$ [9, 10]. The frequency dependence of the threshold voltages for these cholesteric-nematic mixtures and the corresponding pure nematic are very similar [11], the sign of $\Delta\epsilon$ being the determining factor. A cholesteric-WI mixture makes it possible again to check this result within the same sample. In fig. 3 curve a shows the results for a mixture of WI and 4 weight % cholesteryl nonaoate. The threshold voltage was found to be about 25% higher in the small pitch region than in the long pitch region of a planar structure between two successive Grandjean–Cano disclination lines. The threshold voltage V_c was always measured in the largest pitch region. Comparison of figs. 2 and 3

shows that the frequency dependence of the threshold voltage in nematic and cholesteric WI is indeed very similar. The period of the grid-like pattern did not change with the frequency.

The width of the high-frequency conduction regime $\Delta f = f_c - f_0$ was found to be proportional to the conductivity σ of the sample. This is illustrated in fig. 3. We conclude that the behaviour of WI above f_0 is very similar to that of a nematic with negative $\Delta\epsilon$ (as e.g. MBBA) above zero frequency. According to ref. [12] the frequency dependence of the threshold field is given by: $[1 + (f/f_\tau)^2] / [(f/f_\tau)^2 \Delta\epsilon + \theta_H]$, where $f_\tau = \sigma_{\parallel} / \epsilon_{\parallel}$ (~ 400 Hz). This formula does not account for the above effects even if the frequency dependence of $\Delta\epsilon$ is included. The derivation of this formula however is easily extended including the dielectric loss due to the relaxation of ϵ_{\parallel} , leading to both the correct width and a linear conductivity dependence of Δf . Detailed calculations will be given elsewhere.

We wish to express our gratitude to Dr. R. Steinsträsser (E. Merck) for making WI available to us, and to Th. W. Lathouwers for technical assistance.

References

- [1] G. Meier and A. Saupe, in: Liquid crystals, eds. G. H. Brown, G. J. Dienes and M. M. Labes (Gordon and Breach, 1966) p. 195.
- [2] A. J. Martin, G. Meier and A. Saupe, Disc. Faraday Soc. London, December 1971.
- [3] F. Rondelez, D. Diguët and G. Durand, Mol. Cryst. Liq. Cryst. 15 (1971) 183.
- [4] R. Steinsträsser, Angew. Chem., to be published.
- [5] M. Schadt, J. Chem. Phys. 56 (1972) 1494.
- [6] Orsay Liquid Crystal Group, Mol. Cryst. Liq. Cryst. 12 (1971) 251, and references therein.
- [7] H. Gruler and G. Meier, Mol. Cryst. Liq. Cryst. 12 (1971) 289.
- [8] W. H. De Jeu, C. J. Gerritsma and Th. W. Lathouwers, Chem. Phys. Letters, to be published.
- [9] C. J. Gerritsma and P. van Zanten, Phys. Letters 37A (1971) 47.
- [10] F. Rondelez and H. Arnould, C.R. 273 (1971) 549.
- [11] F. Rondelez, H. Arnould and C. J. Gerritsma, Phys. Letters 28 (1972) 735.
- [12] E. Dubois-Violette, P. G. de Gennes and O. Parodi, J. Phys. 32 (1971) 305.