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Electrohydrodynamic instability in some nematic cyanobiphenyls in an a.c. electric field

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Electrohydrodynamic instability in homeotropically oriented nematic samples of 4′-*n*-octyl-4-cyano-biphenyl and 4′-*n*-alkyloxy-4-cyanobiphenyl, ($n = 8, 9$) have been studied in an a.c. electric field. The domain patterns during the instability in these compounds in a very low frequency a.c. field are very similar to those in a d.c. field. The domain patterns observed at higher frequencies have been identified as 'maltese crosses' or 'crossed isogyres'. The electro-convective 'isotropic' flows near the electrode play an important role in the observed instability.

A cellular or roll-like domain pattern was first observed in homeotropically oriented nematic 5CB (4′-*n*-pentyl-4-cyanobiphenyl) [1] and subsequently in 8CB [2, 3] in a d.c. electric field. This instability has been named as 'Felici-Benard' type (FBI) on account of its similarity to the Felici and Benard type of instability. The nature of the instability in an a.c. field is not known for this type of compound (i.e. with $\Delta\varepsilon \gg 0$).

Various instability modes in homeotropically oriented nematic liquid crystals with $\Delta\varepsilon > 0$ is not well understood. Therefore, systematic studies of EHD instabilities in homeotropically oriented nematic cyanobiphenyls have been completed to provide a better understanding of the phenomena. Highlights of our detailed studies have been reported here.

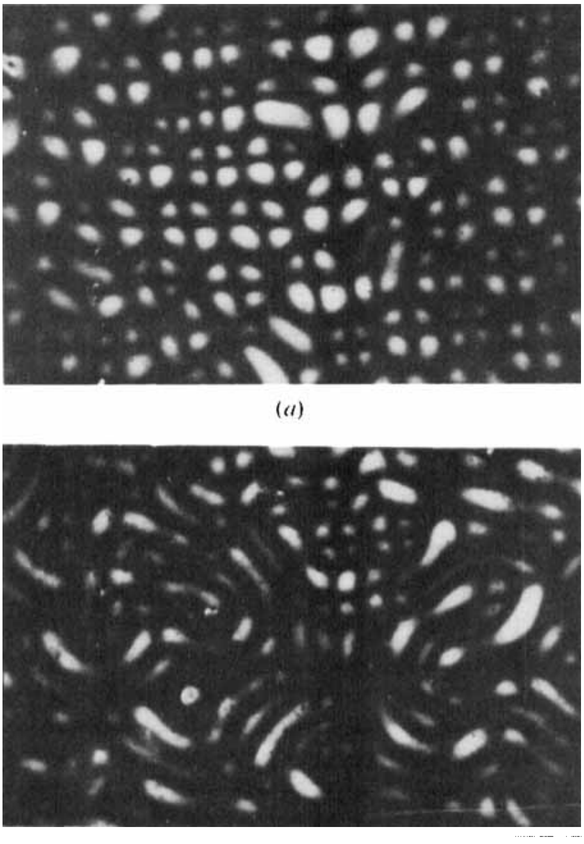
The liquid crystal compounds have been obtained from M/s BDH Ltd., U.K. and were used without further purification. The reported transition temperatures while heating [4] (below) have been confirmed by microscopic observation using a hot stage designed in our laboratory [2] and using a Mettler FP82 hot stage and a Censico polarizing microscope.

8CB : K 21·5°C S_A 33·5°C N 40·5°C I
8OCB: K 55·0°C S_A 67°C N 80°C I
9OCB: K 64°C S_A 77°C N 80°C I

where K, S_A, N and I are the solid, smectic A, nematic and isotropic phases respectively. For the application of an electric field to the samples, SnO_2-coated glass plates were used. Mylar spaces of 50 μm and 75 μm thick were used to determine the cell thickness. Homeotropic alignment was obtained by pre-treating the glass plates with cetyl trimethyl ammonium bromide (CTAB). An a.c. electric field was applied to the sample cell using a function generator (HIL 2821) in the frequency range 0·1 Hz to 20 kHz.

From the microscopic examination, initial homeotropic alignment was found to be very good. The domain patterns appear as maltese crosses/crossed isogyres at a threshold voltage V_{th}. The domain pattern in all the three compounds are basically same. Salient features of the domain patterns of the compounds observed in an a.c. field are as follows:

(1) The domain pattern at very low frequencies (< 10 Hz) are similar to those observed in a d.c. field [1, 2, 3].
(2) For $10\,\text{Hz} < f < 100\,\text{Hz}$, the elongated domain patterns gradually diminish and only a mixture of maltese crosses and elongated domains are observed (figure 1 (*a*)).
(3) Above 100 Hz frequency, only maltese crosses are visible (figure 1 (*b*)). Elongated domains are not observed at all at higher frequencies.



(*a*)

(*b*)

Figure 1. (*a*) Maltese crosses along with elongated domains at 5 V, 20 Hz for 8CB. (*b*) Only maltese crosses without elongated domains at 9 V, 200 Hz for 8CB.

(4) At high electric field ($0{\cdot}5\,\text{kV}\,\text{cm}^{-1}$), the fluid flow is clearly visible, which destabilizes the domain pattern but no dynamic scattering was observed.
(5) The instability appears in the form of vortex flows localized in narrow layers near the electrodes. The fluid flow persists even in the isotropic liquid phase.

The threshold voltage for the vortex flow is equal to that of domain patterns. A circular flow of impurity particles are also observed in the liquid phase and the flow is perpendicular to the initial alignment of the molecules and in the plane of the glass plates.

The response time (i.e. the time required by the domain patterns to appear fully after the voltage is switched-on) is very slow (10–15 s).

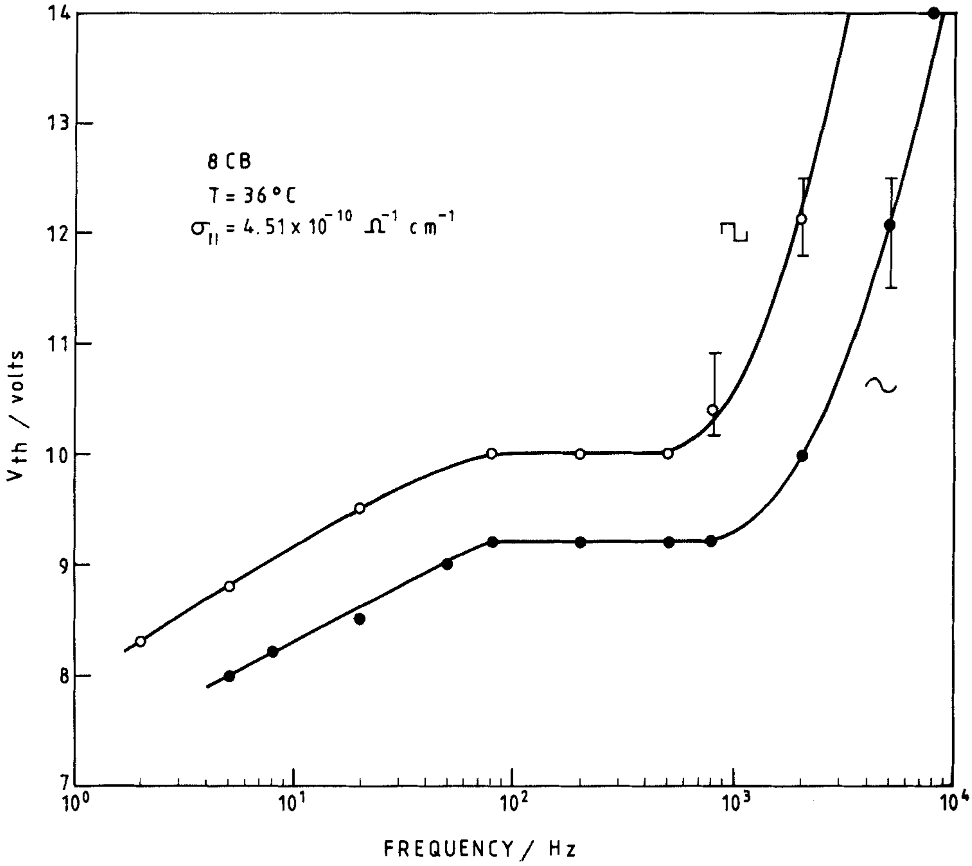


Figure 2. Frequency dependence of the threshold voltage (V_{th}) for 8CB.

Figures 2–4 show the threshold-frequency voltage (V_{th}–f) characteristics for 8CB, 8OCB and 9OCB respectively. Similar type of characteristics was found for all the three compounds except small variation in V_{th} and the frequency range for different instability modes. The general features of the V_{th}–f characteristics are as follows:

(*a*) In the very low frequency region, V_{th} increases slowly with increasing frequency until a plateau (in V_{th}) is observed. The width of the plateau is found to be different for different compounds. It has also been seen that the plateau will be more pronounced with the ageing of the sample, which happened in the case of 8CB.

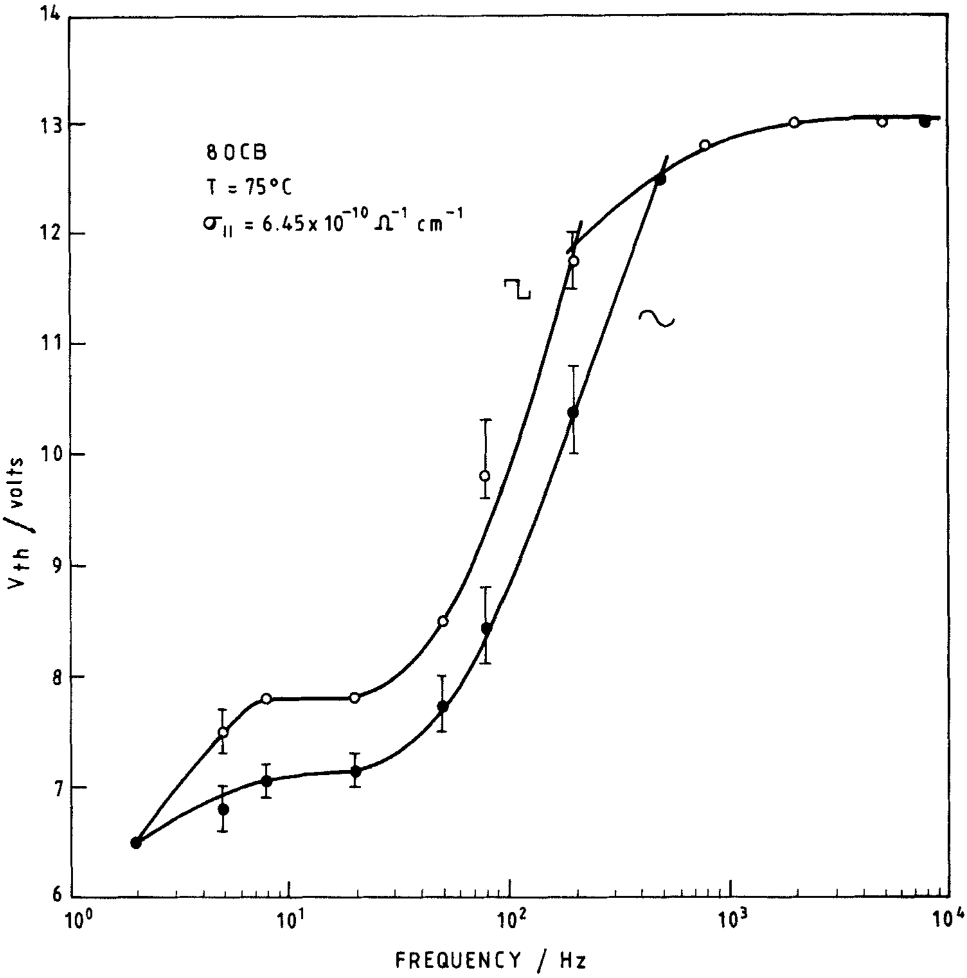


Figure 3. Frequency dependence of the threshold voltage (V_{th}) for 8OCB.

(*b*) Beyond the plateau region, V_{th} increases steeply at a frequency, called the critical frequency, f_c, which also depends greatly on the ageing of the sample. For a fresh sample, f_c is in the region of 10^2–10^3 Hz. For a square wave excitation, f_c is lower than that of sine wave excitation as expected.

(*c*) Above f_c, V_{th} increases with the frequency rather slowly.

As far as the authors know, the above type of V_{th}–f characteristics have not been reported anywhere for homeotropically aligned nematic liquid crystals with $\Delta\varepsilon > 0$. At low frequency (< 10 Hz), the instability is primarily due to the Felici injection mode, which normally occurs in a d.c. or low frequency a.c. field [2]. The charge injection from the electrode surface causes the space charge to build-up near the cathode and as a result of which convective flow occurs. This is analogous to the Benard's problem of thermal convection.

With increasing frequency of the applied field, the variation of the space charge (δq) becomes out of the phase with the external field. Thus the effective force exerted

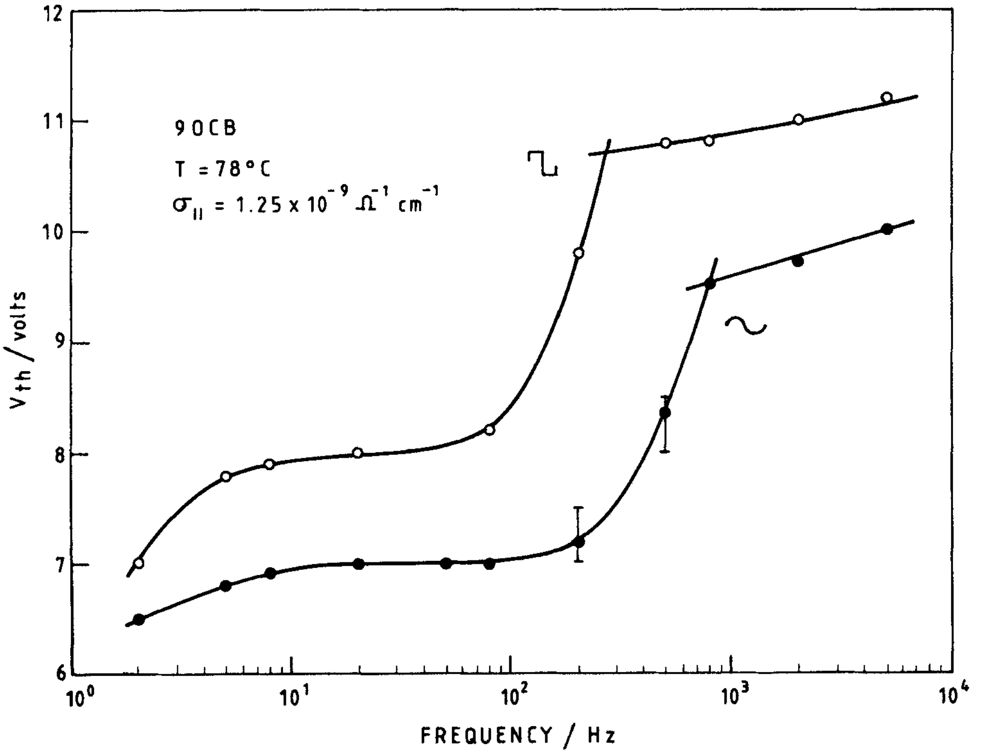


Figure 4. Frequency dependence of the threshold voltage (V_{th}) for 9OCB.

by the external field on the space charge decreases. Hence to create an instability, the external field has to be increased. However, with further increase in the applied frequency ($>f_c$), the charge injection from the electrode surface does not exist any more. The space-charge formation seems to occur due to the electrolytic separation of positive and negative charges by the application of electric field itself. The electric field produces a destabilizing force ($E \cdot \delta q$) just again in the same way as a temperature gradient destabilizes a liquid placed in gravitational field (Benard problem).

Figure 5 shows the variation of V_{th} with the temperature of the mesophase. V_{th} decreases monotonically with the temperature in contrast to the observation of Blinov *et al.* [5], where there is a small increase in V_{th} values at the N–I transition for nematic liquid crystals with $\Delta\varepsilon > 0$. The voltage at which the impurity particles present in the sample start moving in the isotropic state is almost equal to V_{th} in the nematic phase. The continuity in V_{th} at the N–I transition has been observed by us, which confirms the isotropic nature of the instability.

In summary, the instability in a homeotropically oriented nematic liquid crystal with $\Delta\varepsilon \gg 0$ in a stabilizing a.c. field is due to the electro-convective fluid flow caused by the non-uniform charge distribution in the sample. In view of the present classification of different modes of instability [6], the results in the present compounds can not entirely be classified. In order to be more assertive, the above studies in other liquid crystals with $\Delta\varepsilon \gg 0$ other than cyanobiphenyl are necessary.

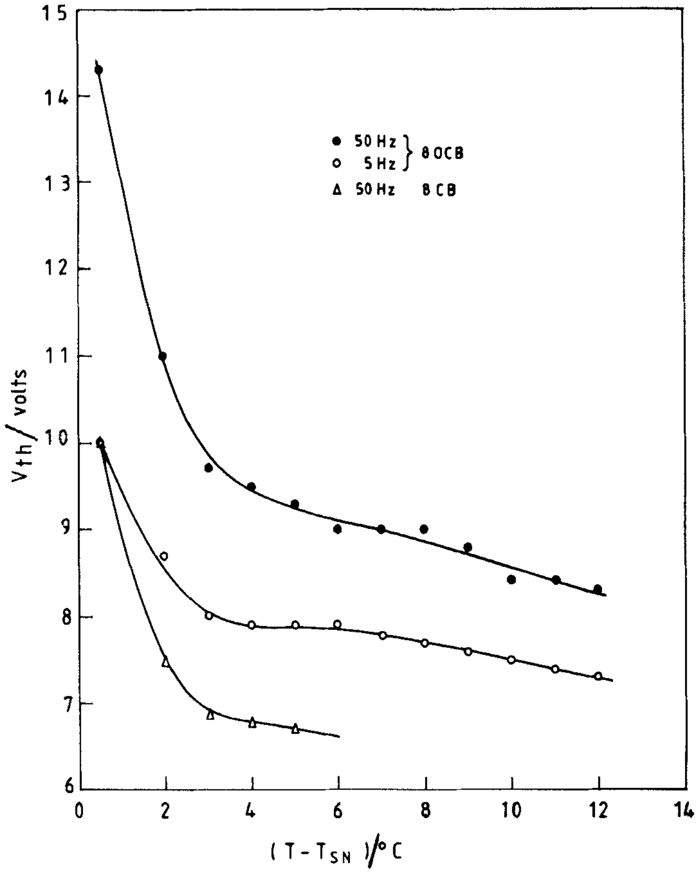


Figure 5. Variation of V_{th} with temperature for 8CB and 8OCB.

References

[1] Nakagawa, M., and Akahane, T., 1983, *J. phys. Soc. Japan*, **52**, 3773; 1983, *Ibid*, **52**, 3782.
[2] Rout, D. K., and Choudhary, R. N. P., 1988, *Molec. Crystals liq. Crystals*, **154**, 241.
[3] Rout, D. K., and Choudhary, R. N. P., *Physics Teacher* (Indian Physical Society).
[4] Data sheet supplied by B.D.H. Ltd., U.K.
[5] Blinov, L. M., Trufanov, A. N., Chigrinov, V. G., and Barnik, M. I., 1981, *Molec. Crystals liq. Crystals*, **74**, 1.
[6] Blinov, L. M., 1986, *Sci. Prog.*, **70** (278), 263.