SOME ELECTROHYDRODYNAMIC DISTORTION PATTERNS IN A NEMATIC LIQUID CRYSTAL

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ABSTRACT

Distortion patterns in a homeotropically aligned nematic liquid crystal (*n-p*-methoxybenzylidene-*p*-butylaniline) under the action of electric fields have been studied employing a geometry in which the observation direction is along the optic axis of the undistorted specimen and the field direction perpendicular to it. Some interesting new features are described.

INTRODUCTION

WILLIAMS[1] was the first to observe that a thin sample of a nematic liquid crystal subjected to a DC electric field exhibits striations when the applied voltage exceeds a certain threshold value. Studies of these distortion patterns have since been extended to low frequency AC fields[2]. The experimental set up generally consists of two transparent electrodes between which the specimen is sandwiched, and the observations are made along the direction of the electric field. In the case of a liquid crystal whose dielectric anisotropy is negative a homogeneously aligned specimen shows striations *perpendicular* to the initial orientation of the director. The pattern is now known to arise from a hydrodynamic cellular motion of the fluid; the motion has been explained in terms of the anisotropy of electrical conductivity of the liquid crystal, which is usually positive (the Carr-Helfrich model)[2,3]. A small bend distortion in the medium produces a space charge in that region because of the conductivity anisotropy. The action of the applied electric field on the space-charge leads to the hydrodynamic cellular flow, which in turn increases the initial distortion until a stable pattern is obtained. At higher voltages, the pattern breaks up and the medium goes over to the dynamic scattering mode.

Recently Williams[4] employed another geometry in which the direction of observation was transverse to the applied field. A homogeneously oriented specimen was sandwiched between two glass plates, one of which had deposited on it two parallel electrodes about 1 cm apart. A DC electric field gave rise to striations perpendicular to the initial direction of orientation of the molecules. More recently these observations have been extended by Richardson and Chang[5] who used much smaller spacings between the electrodes. In the present study we have made observations transverse to the applied field on a *homeotropically* aligned specimen. Some new features have been noted which are described in this paper.

DC EXCITATION

A sample of *n-p*-methoxybenzylidene-*p*-butylaniline (MBBA) was homeotropically aligned between two glass plates, which were separated by two parallel copper electrodes ~ 30 μm thick. The gap between the electrodes was ~ 150 μm and the specimen was observed in a direction perpendicular to the glass plates through a polarizing microscope. The resistivity of the sample was ~ 10^9 ohm cm.

In the absence of any applied field, the specimen in this configuration is dark between crossed nicols, the optic axis being parallel to the direction of observation. If a DC field is now applied no changes are observed at low voltages since the dielectric anisotropy of the medium is negative. At higher voltages (~ 12 V), the anisotropy of conductivity forces the medium to acquire some alignment along the field and there is no longer any extinction between crossed nicols set at 45° to the field direction. The alignment increases with increasing field and at ~ 20 V alternate bright and dark bands appear, and intense agitation can be seen. If the voltage is maintained at 35 V for some time, a regular, periodic though complex pattern is obtained. Figure 1 *a* shows a photograph of the pattern taken between crossed nicols. As the voltage is raised to ~ 40 V, dynamic scattering sets in and the regular pattern is lost.

AC EXCITATION

The pattern assumes simpler shapes under the action of low frequency AC fields. At 20 cps, the response for low voltages is similar to the DC case. At 24 V, a regular distortion sets in. Figures 1 *b*, 1 *c*, and 1 *d* illustrate the patterns obtained at about 32 V for different settings of the nicols. In the setting corresponding to Fig. 1 *c*, dark bands are seen to sweep across the domains from one wall to the other and back, the bands in adjacent domains moving in opposite directions. There are corresponding changes in the walls but these are better seen only when the nicols are set at 45° to the direction of the field. The width of each domain, *i.e.*, the horizontal spacing in the pattern is approximately half the separation between the electrodes. Dust particles can be clearly seen to execute circular motion with a period of a few seconds. As the voltage is increased to ~ 40 V, there is intense motion in the medium which has now gone over to the dynamic scattering mode.

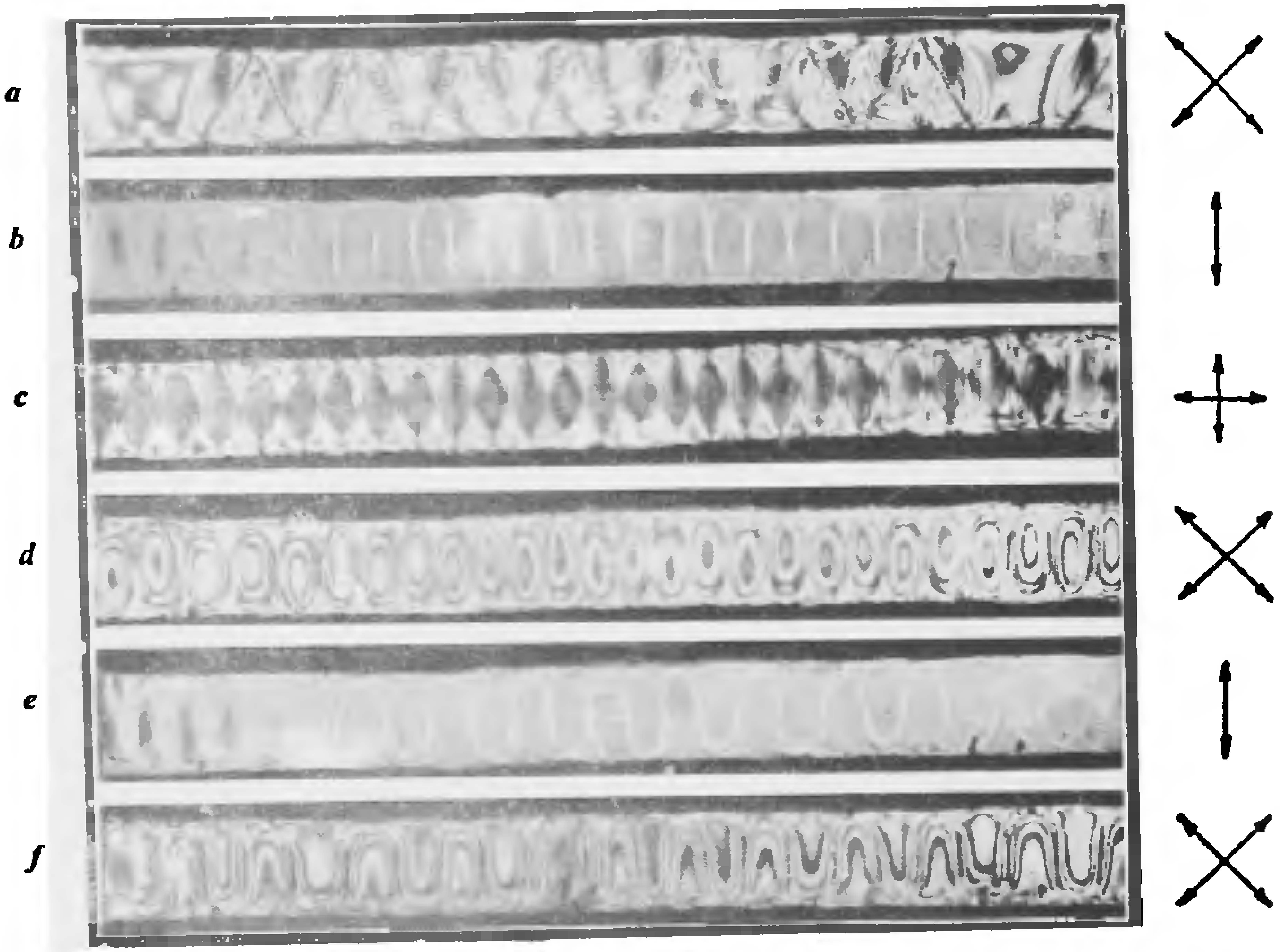

FIG. 1. Electrohydrodynamic patterns in MBBA. Photographs taken in monochromatic light (λ 5893 Å); magnification × 75. In all cases, the applied electric field is vertical and the director of the undistorted specimen is parallel to the direction of observation. The arrows on the right hand side indicate the settings of the nicols. (*a*) DC, 35 V; (*b*), (*c*) and (*d*) 20 cps, 32 V; (*e*) and (*f*) 100 cps, 45 V. (The horizontal lines in the centre of each photograph are the graduations in the microscope eye-piece.)

An increase in the frequency of the applied field results in an increase in the threshold voltage at which the distortion sets in. Figures 1 *e* and 1 *f* illustrate the wavy pattern obtained at 100 cps and 45 V. It is seen that the spatial periodicity of the distortion has increased compared to the lower frequency case.

At still higher frequencies (~ 250 cps) the homeotropic alignment improves when the voltage is less than about 25 V, but at about 30 V the orientation near the electrodes becomes parallel to the field as evidenced by two bright patches between crossed nicols set at 45°. At higher voltages (~ 42 V), a wavy distortion begins to grow laterally from both sides of the field of view. On increasing the frequency further, the regular distortion becomes less and less conspicuous though some hydrodynamic motion persists upto ~ 800 cps at high fields. Beyond this frequency there is only a small, irregular motion near the electrodes at very high voltages (~ 500 V).

As the separation between the electrodes is increased to 1–2 mm the regular distortions especially under low frequency AC fields are confined to the neighbourhood of the electrodes at low voltages and grow to join up at higher voltages. A similar effect has also been observed by Williams[4] for the configuration employed by him.

Detailed measurements of related optical and electrical characteristics are under way and will be published in due course.

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2. Dubois-Violette, E., de Gennes, P. G. and Parodi, O., *J. Phys.*, 1971, 32, 305.
3. Helfrich, W., *J. Chem. Phys.*, 1969, 51, 2755.
4. Williams, R., *Ibid.*, 1972, 56, 147.
5. Richardson, J. M. and Chang, R., *Proceedings of the Fourth International Liquid Crystal Conference*, Kent, Ohio, August 1972.