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Characteristics of a bi-Dimensional Structure in Twist Cells with Nematic Liquid Crystals†

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A bi-dimensional structure in MBBA is studied in the conduction region by microscopic observations using twist geometry cells with zero tilt angle at the electrodes.

The distance d between equidistant discontinuities, perpendicular to the Williams domains, is determined as a function of voltage U, temperature T, frequency f and cell thickness h.

One obtains a single reduced curve d/d_w versus U/U_w (d_w-period of Williams domains at threshold voltage U_w), which indicates that the various parameters control the reduced period d/d_w only by way of the reduced voltage U/U_w.

1 INTRODUCTION

The formation in nematics with negative dielectric anisotropy, in the conduction region, of a bi-dimensional structure, consisting of Williams domains interrupted by discontinuities was dealt with in a series of papers.

Goscianski and Leger[1] observed a structure of this type at temperatures a little above the smectic-nematic transition point, interpreting it as the remanence of a smectic ordering in the nematic phase.

† Results presented at the 1st Liquid Crystals Conference of Socialist Countries (Halle, GDR, 1976). The work was supported by the Romanian Nuclear Energy Committee.

In a paper of Berman, Gelerinter and de Vries,[2] the appearance of a bi-dimensional structure is reported when low frequency a.c. electric and d.c. magnetic fields are applied to some nematic liquid crystals. These authors are also putting the observed structure to the account of a smectic ordering, although the nematic liquid crystals they studied did not present a smectic phase at lower temperatures.

Theoretic considerations developed by Pikin, Ryschenkow and Urbach[3] led to the conclusion that extraordinary domains, perpendicular to the Williams domains, are expected in some conditions for a non zero tilt angle at the electrodes ($\theta_0 \neq 0$). Extraordinary domains were also obtained by the authors, sometimes even in the absence of classical Williams domains.

Bolomey and Dimitropoulos[4] studied the appearance and the development of the bi-dimensional structure by increasing the applied electric field and they determined the values of the distances between the discontinuities for different frequencies, temperatures, applied voltages and thicknesses of the liquid crystal cells.

In all the mentioned papers, in which the experiments were performed on cells with a planar geometry, the authors noted the oscillatory character of the bi-dimensional structure.

In the present paper, we are still studying the characteristics of a bi-dimensional structure of this type in the conduction region, but on twist cells.

The molecular alignment was achieved by rubbing; one may assume then an approximately zero tilt angle at the electrodes ($\theta_0 = 0$).

Preliminary experiments effected on cells with planar and with twist geometry showed the more stable character of the bi-dimensional structure in the latter type of geometry, a behaviour mentioned also in.[5] This is why we chose the twist geometry for the experiments reported here.

It is to be mentioned that bi-dimensional structures were reported in cholesterics,[6] which possess a natural twisted structure.

2 EXPERIMENTAL

The microscopic observations in polarized light were effected on closed cells with twist geometry 10, 15, 25 and 50 μm thick.

When not otherwise specified, the measurements were performed between crossed polars, the polarization direction of the incident light coinciding with the molecular orientation near the entrance glass plate.

The nematic liquid crystal was MBBA—Eastman Kodak no. 11246-, without any added dopant, and having an electrical conductivity of about $10^{-9}\Omega^{-1}\,cm^{-1}$.

The cell was placed in a water-thermostated chamber, made in the laboratory. The temperature in this chamber was measured by means of a thermocouple introduced in a similar cell, situated near the cell used for observations, the temperature being maintained constant within 0.1°C.

A heat filter avoided the heating of the cell by absorption of i.r. radiant energy.

3 RESULTS

By voltages just above the threshold value, short and generally undulated discontinuities frequently appear, being oriented more or less perpendicular to the length of Williams domains. Such discontinuities, familiar to everybody performing microscopic observations in the conduction region, are shown in Figure 1.

The number of the discontinuities grows at higher voltages; they get longer, come into connection with each other and, after a few minutes, arrange themselves as parallel, equidistant lines, perpendicular to the Williams domains. In Figure 2 one can see three discontinuity patterns superimposed on the Williams domains (forming thus bi-dimensional structures) obtained in the same cell at three different voltages.

The increase of the applied voltage brings about a diminution of the distance d between the equidistant discontinuities. In the following we shall call this distance the "period".

At higher voltages, the domains interrupted by discontinuities turn into a pattern of square cells, as seen in Figure 2c.

FIGURE 1 The aspect of the discontinuities at a voltage near the Williams domains threshold U_w.

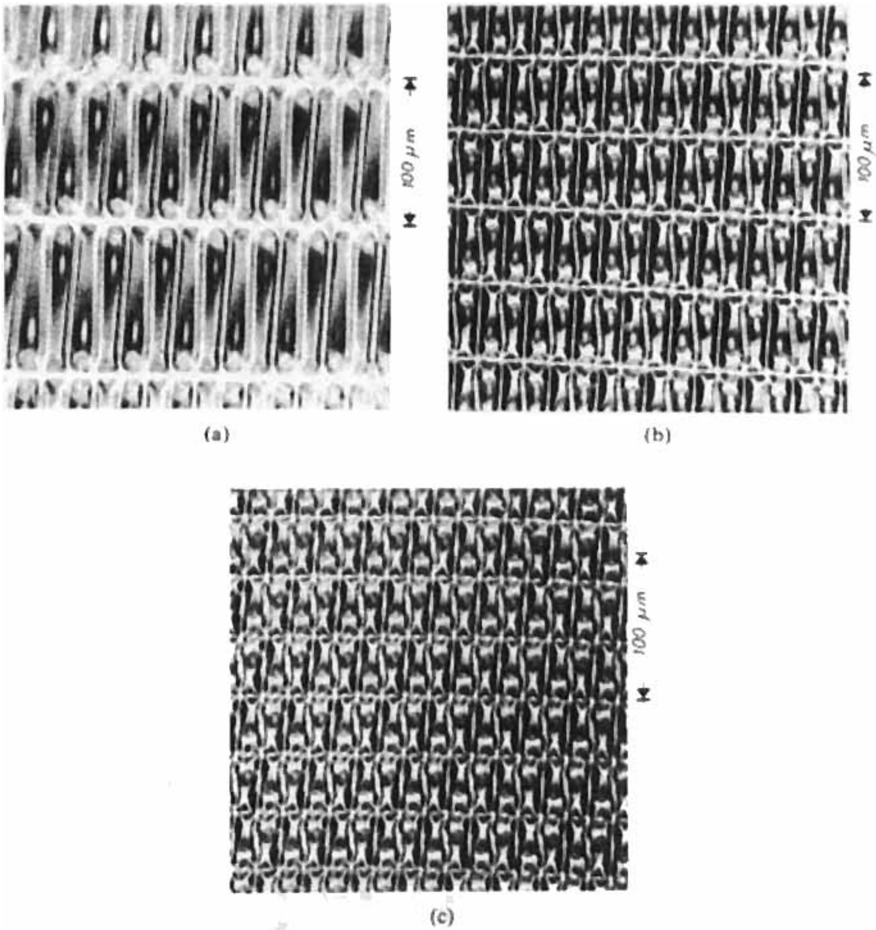

FIGURE 2 Bi-dimensional structures at different voltages Room temperature, $h = 25\ \mu m$, $f = 250$ Hz, (a) $-U = 12.5$ V; (b) $-U = 15.5$ V; (c) $-U = 18$ V.

It is worth mentioning that the width of a discontinuity line decreases with increasing voltage, so that in the pattern of square cells a discontinuity line looks like a Williams domain line.

The voltage at which the bi-dimensional structure may be observed is limited towards low values by the fact that the discontinuities cease to form a set of parallel and equidistant lines, and towards high values by the appearance of an instability of the pattern, which precedes the setting up of the dynamic scattering.

As mentioned in[4] the period d depends on voltage U, frequency f, temperature T and thickness h of the cell.

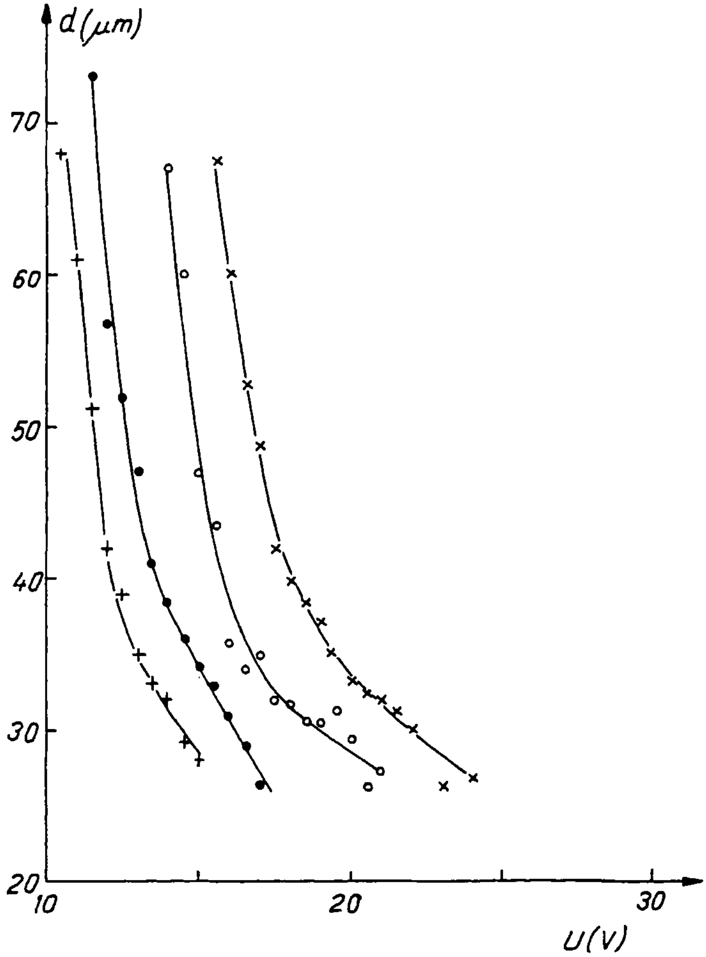

FIGURE 3 Period d versus voltage U: h = 25 μm, f = 55 Hz; + ——20.6°C; ● ——18.1°C; ○ ——16.1°C; × ——15.1°C.

Figure 3 renders the results at a constant frequency, with T as a parameter. One can see that d diminishes by increasing U, as mentioned before, the same period being obtained at smaller voltages for higher temperatures.

One must stress that the extreme values of the period are practically the same, regardless of the temperature†.

The results obtained at a constant T and at several frequencies are presented in Figure 4.

† As seen in Fig. 3, some measurements were performed in the domain of supercooling.

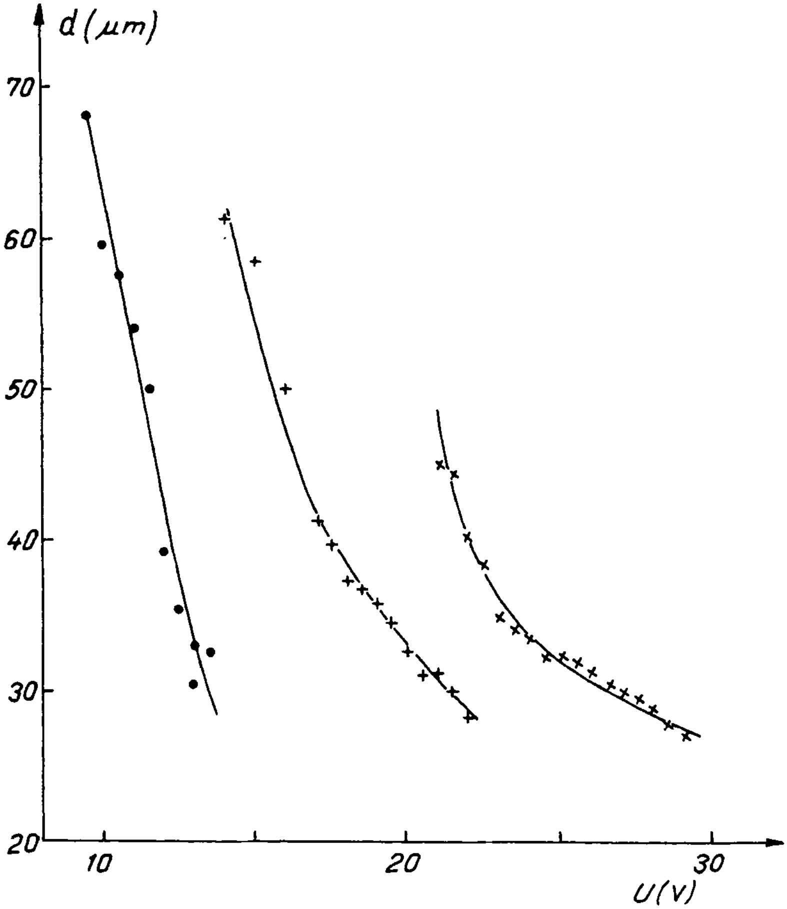

FIGURE 4 Period *d* versus voltage *U*; $h = 25\ \mu m$; $T = 17.1°C$; ● ——35 Hz; + ——60 Hz; × ——80 Hz.

It is necessary to emphasize that the studied bi-dimensional structure appears at any frequency below the cut-off frequency, unlike the Wright–Dawson[7] structure which is reported to be observable only in a limited region of the conduction domain.

It is to be mentioned that the bi-dimensional structure is not stable for any temperature at which the substance is in the nematic phase; at higher temperatures, by increasing *U*, the dynamic scattering appears without an intermediate formation of the pattern of equidistant discontinuities.

Since the discontinuity structure always appears as being superimposed upon the Williams domains at voltages less than about twice the threshold

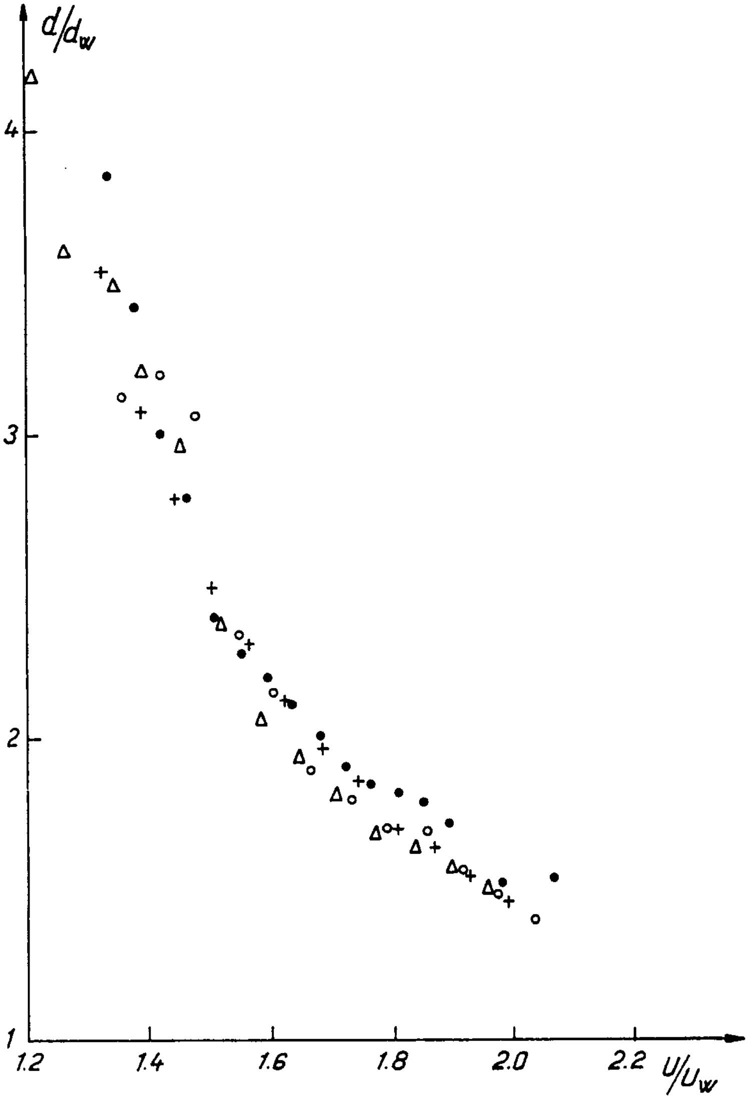

FIGURE 5 Reduced curve d/d_w versus U/U_w for different temperatures; $h = 25\ \mu m$, $f = 55$ Hz ●——15.1°C; +——18.6°C; ○——19.6°C; △——20.1°C.

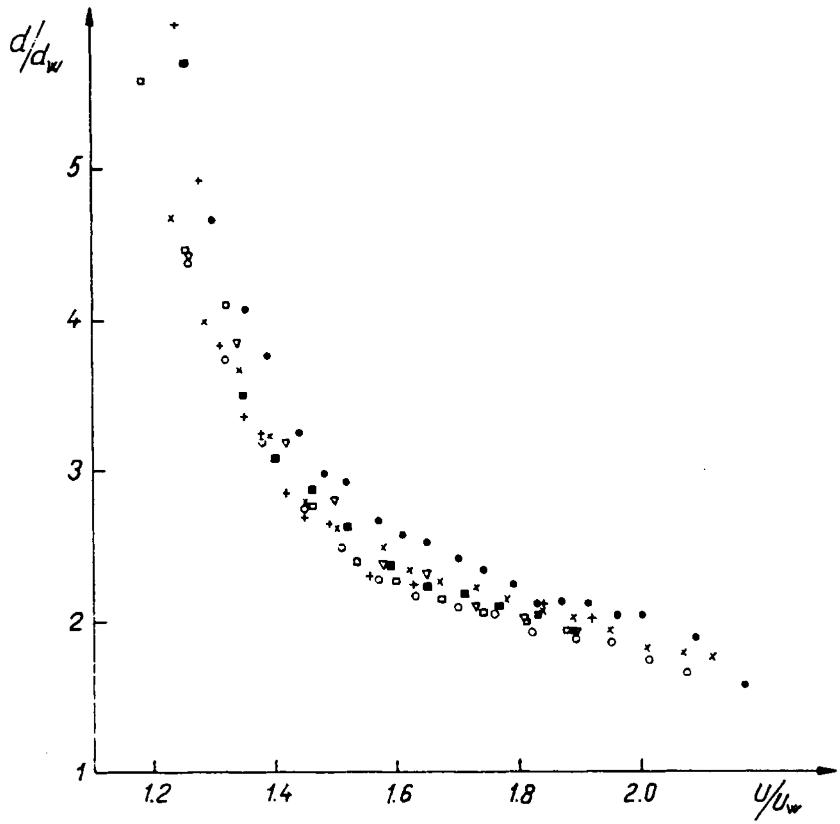

FIGURE 6 Reduced curve d/d_w versus U/U_w for different thicknesses and frequencies, T = 15.1°C;

h = 50 μm { ○ ——55 Hz, ● ——60 Hz, × ——65 Hz } h = 15 μm { □ ——300 Hz, ■ ——350 Hz }

h = 25 μm ▽ ——300 Hz
h = 10 μm + ——120 Hz

voltage U_w for the formation of these domains, we tried to see whether the reduced voltage U/U_w is the single variable controlling the ratio d/d_w, the width d_w of Williams domains at the threshold being itself a function of temperature and frequency.[8]

Figure 5 represents a reduced curve d/d_w as a function of U/U_w, at a constant frequency, plotted by means of values obtained at different temperatures. One may see that the points corresponding to values measured at

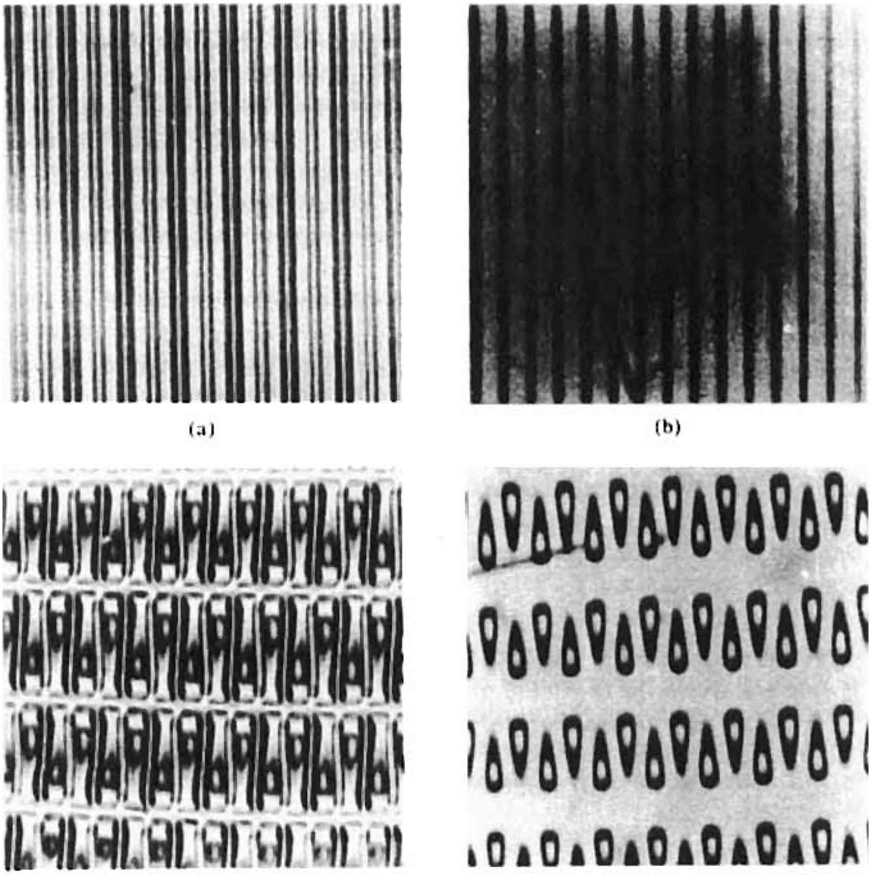

FIGURE 7 Aspect of Williams domains above threshold and of the bi-dimensional structure for two orientations of the crossed polars 250 Hz, room temperature: (a) Williams domains at 10.5 V; polarizer parallel to the director at the entrance glass plate. (b) Williams domains at 10.5 V; polarizer perpendicular to the director at the entrance glass plate. (c) bi-dimensional structure at 13.1 V; polarizer parallel to the director at the entrance glass plate. (d) bi-dimensional structure at 13.1 V; polarizer perpendicular to the director at the entrance glass plate.

various temperatures are situated (within the limits of experimental errors) on a single reduced curve.

The reduced curve in Figure 6 was plotted using measurements effected at a single temperature, but at several frequencies, on cells with various thicknesses h.

The existence of reduced curves, as are those represented in Figures 5 and 6, leads to the conclusion that the parameters T, f and h do influence the value of the ratio d/d_w only by way of the reduced voltage U/U_w.

Like Williams domains in cells with twist geometry, the bi-dimensional structure is best visible between crossed polars when the polarization direction of the incident light coincides with the molecular orientation near the entrance glass plate. Nevertheless, the bi-dimensional structure, especially when formed of square cells, does not disappear completely for a 90° rotation of the polars, but only changes its aspect. In relation to the above, it is to be mentioned that the Williams domains in twist geometry become structured at voltages above the threshold, some of their components remaining visible also after the 90° rotation of the polars.

Figure 7 shows the aspect of the Williams domains observed at voltages above the threshold (Figure 7a and b) and of the bi-dimensional structure (Figure 7c and d) for two orientations of crossed polars, namely for the polarizer parallel and the polarizer perpendicular to the director at the entrance glass plate, Figure 7a and c, and 7b and d, respectively.

One may remark that the parts of the bi-dimensional structure visible in 7d originate from components of Williams domains still observable in 7b.

In conclusion, contrary to the statements of Goscianski and Leger[1] and of Berman *et al.*,[2] we observed a stable bi-dimensional structure in MBBA, at least for a twist geometry.

The fact that in the experiments reported in this paper, effected on twist cells with zero tilt angle ($\theta_0 = 0$), the bi-dimensional structure appears only at voltages above the threshold of the Williams domains, seems to support Pikin's *et al.* assertions.[3] According to these authors, in conditions similar to ours, the formation of a bi-dimensional structure is due to the creation of a non zero tilt angle ($\theta \neq 0$) inside the hydrodynamic vortexes which appear as Williams domains.

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