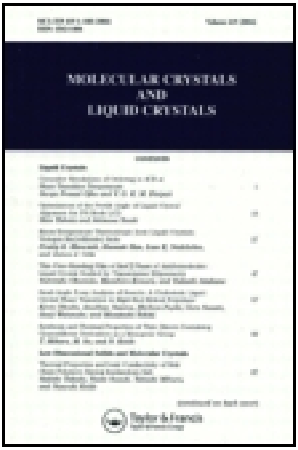

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Defect Transformations in Nematic Liquid Crystal Research Note

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Defect Transformations in Nematic Liquid Crystal Research Note

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The polarizing microscopic textural changes in a thin film (12μ) of a nematic liquid crystal (NLC) p-ethoxy benzylidene -p′-n-butylaniline (EBBA) as it is cooled from its isotropic to the crystal phase, have been examined. No alignment was given to the substrates; no external field was applied. Upon cooling the isotropic (I) melt, the nematic phase (N) begins to separate at the clearing point (77°C) in the form of droplets. Each drop displays a black cross the arms of which are parallel to the vibration directions of the polarizers. Interference fringes are also observed within each drop. The structure of a nematic droplet floating in an isotropic liquid medium have been studied earlier both theoretically and experimentally[1–13] .A theoretical investigation of the structure of droplets of nematic materials, floating in an isotropic liquid has been carried out by Dubois-Violette and Parodi.[1] By assuming an anisotropic surface energy, these authors predict both the possible configurations depending on whether surface tension induces a normal or a tangential orientation of the molecules at the N-I interface. The surface tension of the N-I interface has been calculated in a mean field approximation for the system of rod-like molecules intracting via attraction as well as hard-core repulsion[14]. It is found that the excluded volume effect favours the planar orientation of molecules at the N-I interface in contrast with the case of the nematic free surface at which the effect favours the normal alignment. Thus one can expect that at the N-I interface of EBBA, the surface tension imposes tangential boundary condition on the droplet surface. As a result two

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point defects, classified as boojums are obtained at the poles of the droplets. When such droplets are observed through a polarizing microscope with the droplet axis (direction connecting two poles of the droplet) parallel to the direction of incoming light, the resulting texture is an extinction cross with its arms parallel to analyzer and polarizer respectively, as can be seen in Plate 1. Certain droplets are surrounded by black ring indicating thereby that molecules on the equator of the droplets are exactly parallel to the direction of incoming light.

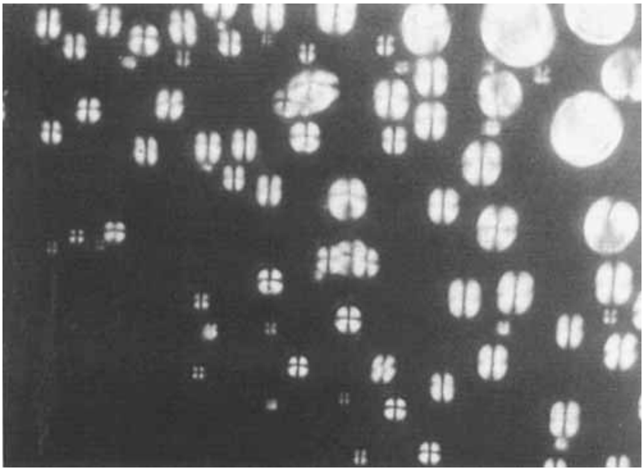

PLATE 1 Separation of nematic phase of EBBA from the isotropic melt in the form of droplets, 76.8°C, crossed polaroids, 400×, 12 μ (See Color Plate I at the back of this issue)

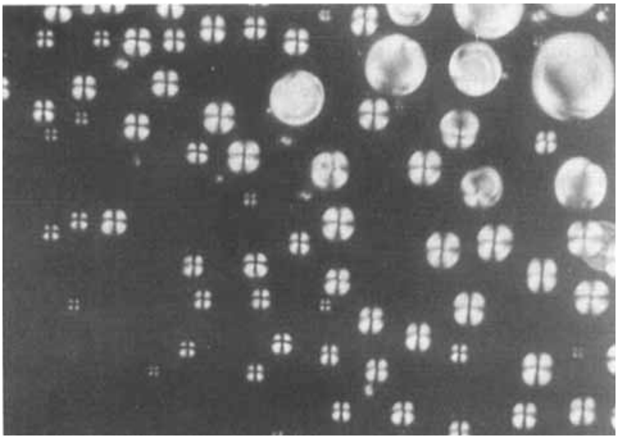

PLATE 2 Nematic droplets with boojums, 76.5°C, crossed polaroids, 400×, 12 μ (See Color Plate II at the back of this issue)

The structure of nematic droplets contain two singular points on opposite sides of the droplet. At each singular point there is a large splay and there is also bending in the structure. Thus curvature induced space charge is produced which is largest near the singular points. Also, splay induces polarization. Thus, one singular point becomes a source of charge and the other a sink and an electric field is produced within the droplet.[6] These droplets (spheres) are brought into contact by thermally induced changes of their radii. (The effect may be recorded by high-speed motion-picture photography). The subsequent dynamics of the disclination configuration produced at the instant of droplet coalescence depends on the orientation of the spheres in the space. Chuvyrov et al[4] have established that when the axes of the spheres (axes connecting poles where boojums exist) with two disclinations on each surface are strictly parallel, a symmetric disclination configuration is produced with four disclinations on the equator with Frank index (+1) and two disclinations with Frank index (-1) at the poles. Two positive disclinations are annihilated by two negative disclinations and a structure with two positive disclinations is produced. In plate 1, the merging of droplets at two places of the sample has been photographed and the resulting texture is shown in plate 2. When the sizes of the droplets approach the thickness of the spacing between the glass substrates, they are not spherical but flattened by the sample substrates to form oblate spheroids (Plate 3). In the oblate cavities the boojums are forced to regions of high curvature to relieve splay and bend elastic deformations. On obtaining a critical size these droplets may breakup into ribbon. And if the internal field within the droplets dominate then under the effect of this field, the droplets may stick together in chains and give rise to thick threads. These structures require a detailed topological study involving defect transformation.

As the temperature reaches 75.5° C, a ribbon like structure appears (Plate 3). The ribbons correspond to a strong maximum of both birefringence and mean index of refraction. In plate 4 thick threads (twist wall) are visible. The topological structure of a twist wall is shown in fig. 1a. In the middle of the thick thread a helical ribbon is also visible.

The temperature is then lowered so that the nematic phase fills the whole cell. The anchoring conditions become degenerate. Now the twist wall (fig. 1a) may get converted into either the structure shown in fig 1b or that shown in fig 1c. When it is converted into a structure like that shown in fig 1b, it forms a sort of elbow of a constant angle (obtuse)[15] (Plate 5, fig 2) The edge at which this bend occurs may be called the reversing edge as there is a reversing of twist on either side of this edge. On following the center of the wall and approching the reversing edge, the director increasingly takes a direction perpendicular to the wall but without modifying the angle with the vertical. Cooling transforms the twist wall into two black branches by means of the movement of a nucleus of half integer

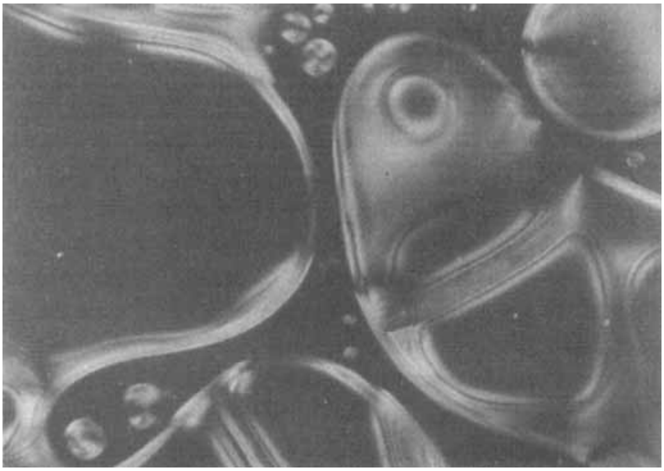

PLATE 3 Nematic droplets with boojums and nematic ribbon like structure, 75.5°c, crossed polaroids, 400×, 12 μ (See Color Plate III at the back of this issue)

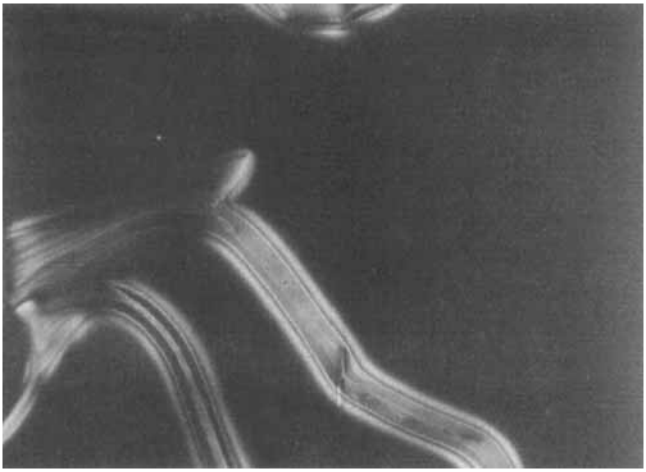

PLATE 4 Thick threads in EBBA, 75°C, crossed polaroids, 400×, 12 μ (See Color Plate IV at the back of this issue)

strength (Plate 6). They constitute inversion walls according to Nehring and Saupe.[16]

In Plate 6, a nucleus of half integer strength dividing the two arms of the twist wall is visible. With the decrease in temperature of the sample, this nucleus moves upwards and when it reaches the edge of the wall, it appears as a wedge disclination of strength – 1 (Plate 8).

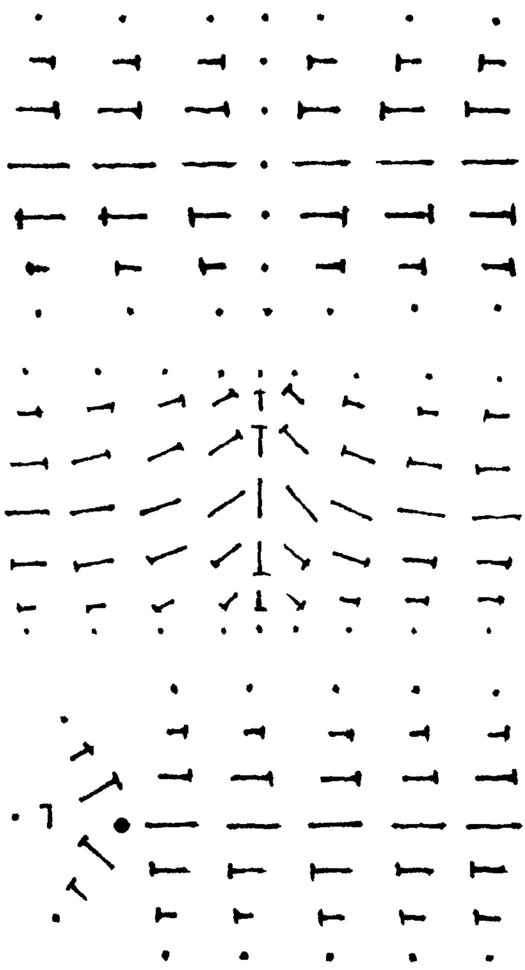

FIGURE 1 Cross-section (in the X-Y plane) of (a) the planar structure of a thick thread (b), (c) the structures that replaces it

One can also observe the motion of a singular point in the twist wall as one goes from plate 5 to plate 10 where it becomes a pinch when it reaches the edge of the wall and meets the inversion line of first kind.

As the temperature reaches 71.5°c, a perfect schlieren texture with black brushes originating from singular points appears (Plate 7). When the strength of two neighbouring disclinations are equal and opposite, the brushes connecting them are circular arcs. An example of such circular brushes can be seen in plate 7.

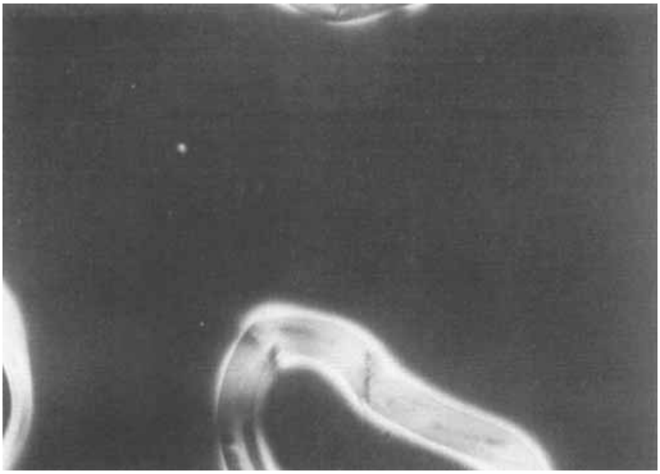

PLATE 5 Twist wall with reversing edge in EBBA, 74°C, crossed polaroids 400×, 12 μ (See Color Plate V at the back of this issue)

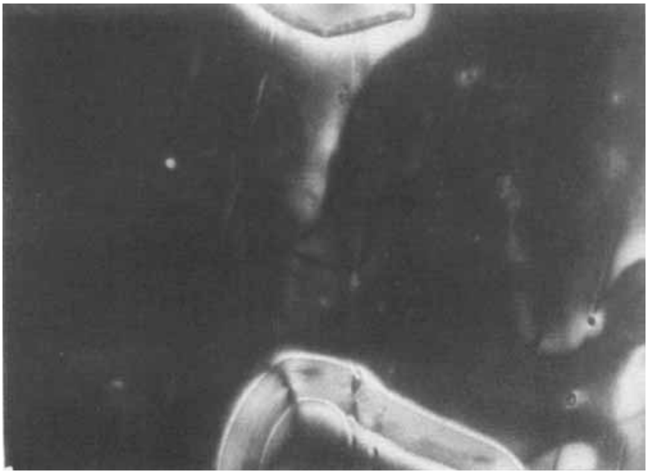

PLATE 6 Appearance of Schlieren texture. In the lower section on the film a twist wall with S = −1/2 nucleus and an other singularity is clearly visible, 73°C crossed polarizers, 400×, 12 μ (See Color Plate VI at the back of this issue)

In plates 9 & 10. We can clearly see the Nematic marbled texture in the background of the twist wall.

PLATE 7 Nematic Schlieren texture with a twist wall, 71.5°C crossed polaroids, 400×, 12 μ (See Color Plate VII at the back of this issue)

PLATE 8 Twist wall with a wedge disclination of strength −1, which appeared because of the upward movement of −1/2 nucleus. The other singularity is also found to reach the edge of the wall, 65°C, crossed polaroids, 400×, 12 μ (See Color Plate VIII at the back of this issue)

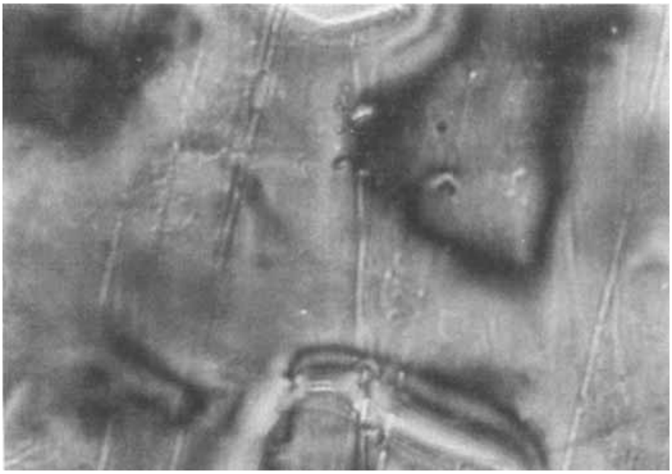

PLATE 9 Inversion wall of the second kind with a pinch, 55°C, crossed polaroids, 400×, 12 μ (See Color Plate IX at the back of this issue)

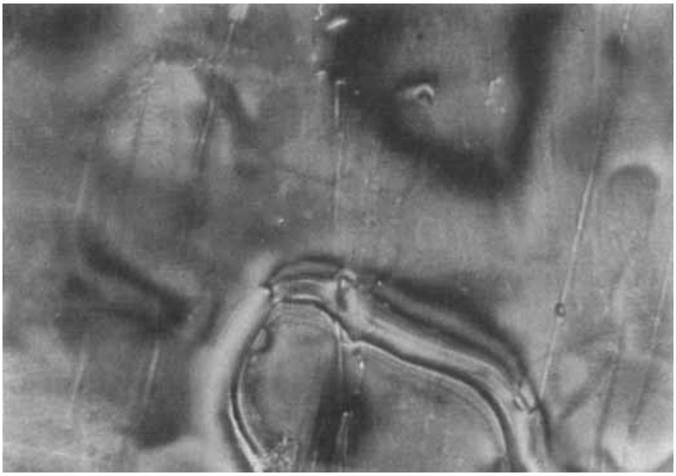

PLATE 10 Nematic marbled texture. Inversion wall of the second kind is also visible 35°C, crossed polaroids, 400×, 12 μ (See Color Plate X at the back of this issue)

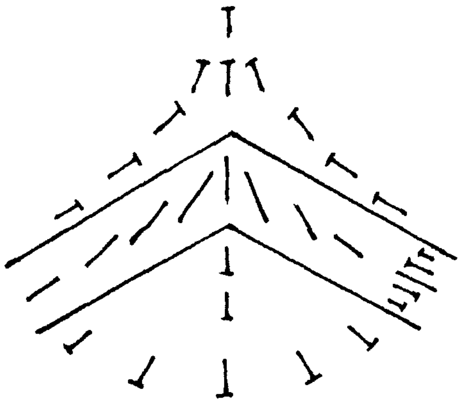

FIGURE 2 Reversing edge in a tilt inversion wall

Acknowledgements

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