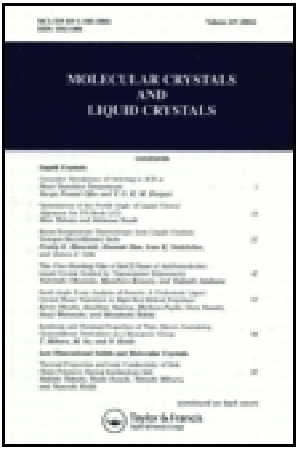

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Bubble Domain in Cholesteric Liquid Crystals

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Bubble Domain in Cholesteric Liquid Crystals†

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Some experiments are reported on the bubble textures obtained in homeotropically aligned cholesterics of large pitch. The variations of the bubble diameter with the thickness and the temperature of the liquid crystal and with an applied electric field are studied. The conditions of the texture erasure by application of an electric or magnetic field are determined.

A domain pattern called bubble domain texture or spherulitic texture has been observed by Haas *et al.*[1] and Kawachi *et al.*[2] in homeotropically aligned cholesterics of large pitch, more precisely in a limited range of the ratio between the pitch p and the thickness d of the liquid crystal layer (nematic-cholesteric mixture). The bubble forming processes and conditions have been discussed by Bhide *et al.*,[3] Nawa *et al.*,[4] Akahane *et al.*,[5] and recently by Stieb.[6]

Generally the bubble forming process is as follows: a dc or low frequency ($\leq$100 Hz) voltage is applied to the cell containing the liquid crystal so that an electrohydrodynamic turbulence is induced and the bubble texture appears spontaneously after the electric field removal. Bubbles can also be generated by raising the temperature of the nematic-cholesteric mixture and then suddenly cooling it to room temperature.[3] The general appearance of this texture which is very stable in time is that of a pattern of small bubbles (diameter of a few tens of μm) the center of each exhibiting a maltese cross between parallel polarizers. By varying voltages and application times it is possible to obtain a large range of bubble densities from isolated bubbles to a packed texture and a hexagonal structure (Figures 1a,b,c). The bubbles can be erased by application of an ac field of high frequency ($\approx$1 kHz) which does not produce DSM.

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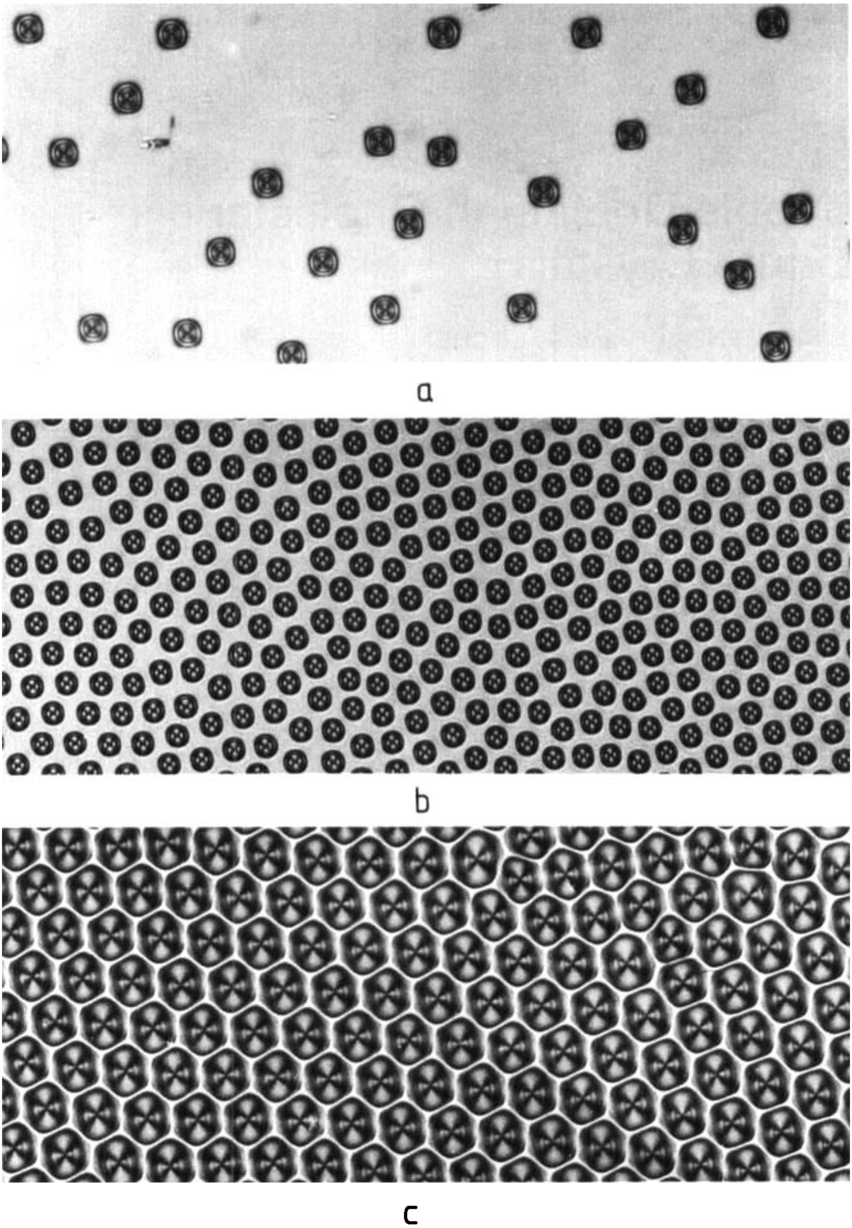


FIGURE 1 Various examples of bubble structures: a) isolated bubbles, b) packed texture, c) hexagonal texture.

It is the purpose of this paper to report some complementary observations on this texture such as the variations of bubble diameter with various parameters and the erasure conditions.

EXPERIMENTAL

The experiments have been performed on various mixtures: a nematic product of negative dielectric anisotropy (MBBA) with a cholesteric of negative (cholesteryl nonanoate, cholesteryl oleyl carbonate COC) or of positive (cholesteryl chloride CC) dielectric anisotropy; the pitches are determined by the Cano wedge method. The mixtures are sandwiched between two tin or indium oxide coated glass electrodes separated by Mylar spacers. Various cell thicknesses d and cholesteric concentrations have been used in order to vary the ratio d/p: typically the thicknesses are between 14 and 40 μm and the cholesteric concentrations of the order of 0.5% (by weight). A homeotropic alignment of the liquid crystal is obtained by a very thin film deposit of hexadecyltrimethylammonium bromide on the electrodes.[7] A low frequency electric field or sudden cooling of the heated mixture will produce the bubble structure, as mentioned above; its erasure can be achieved by application of an ac electric field ($\approx$1 kHz). The structure of the obtained textures is studied by microscopic measurements or in some cases from laser diffraction patterns.

RESULTS

1) In the bubble forming process by application of an electric field it has been found that the threshold voltage required to produce a stable bubble texture increases with the liquid crystal thickness but varies little with the frequency (between 0 and 100 Hz). Typically this voltage is of the order of 10–15 volts. As mentioned above the applied voltage and its application time are interdependent, the time decreasing with an increasing voltage for the same bubble density; it is thus possible to control this density and to obtain isolated bubbles rather than packed textures in which a deformation of the bubbles appears, due to interactions between neighbouring bubble domains. The results described below have been obtained on isolated bubbles in order to avoid this disadvantage.

2) The bubble diameter is larger than the liquid crystal layer thickness, therefore the bubbles have an oblate spheroid shape. The diameter D_0 of the bubbles formed by application of an electric field increases with the layer thickness d (or with the ratio d/p) as shown in Figure 2 for a mixture of MBBA and COC (0.5% by weight); a similar variation was observed for mixtures of MBBA and CC. It has been found that the diameters of bubbles ob-

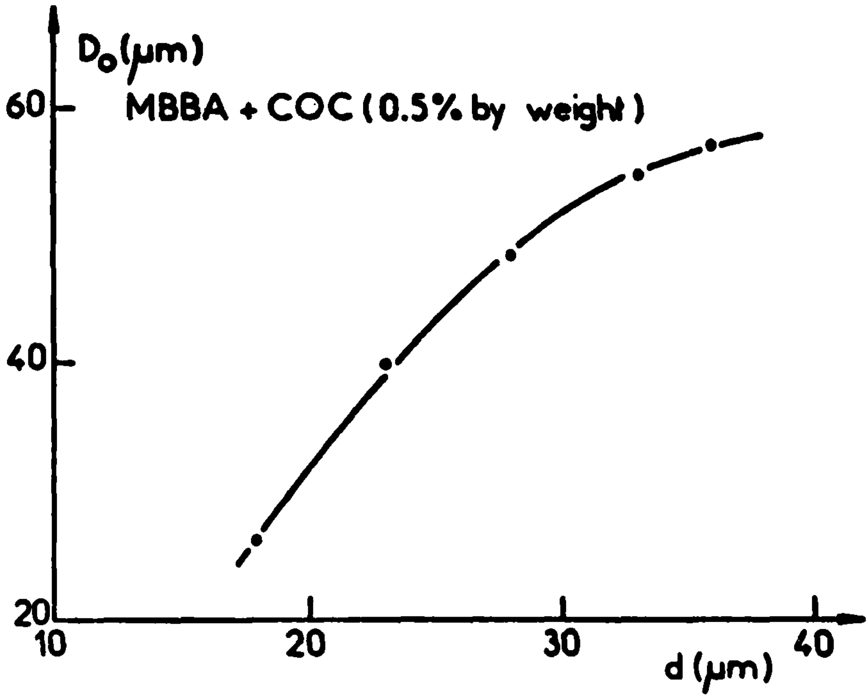


FIGURE 2 Variation of the bubble diameter D_0 *vs.* the liquid crystal thickness *d*.

tained by electric field application and by sudden cooling of the heated mixture are approximately the same for identical conditions of liquid crystal composition and thickness. These bubble textures are very stable in the time; no changes have been observed within several weeks.

3) After formation of the bubbles their diameter D_0 can be modified by increasing or decreasing the liquid crystal temperature T which changes the pitch. For high temperatures instabilities occur leading to bubble disappearance. The variation of D_0 as a function of T, which is reversible, is shown in Figure 3 for a mixture of MBBA and COC (0.5 by weight).

4) The bubble diameter can be also varied by application of a dc or low frequency (≈50 Hz) voltage V; the diameter D increases more and more with V, from a threshold voltage, as shown in Figures 4a,b,c, until an overlapping of the domains occurs leading finally to an electrohydrodynamic instability. The relative variation D/D_0 (D_0 being the bubble diameter without electric field) is plotted in Figure 5 as a function of the electric field V for various conditions. When the ratio d/p increases the diameter variation is more important and appears for lower fields. The voltage threshold decreases also if the

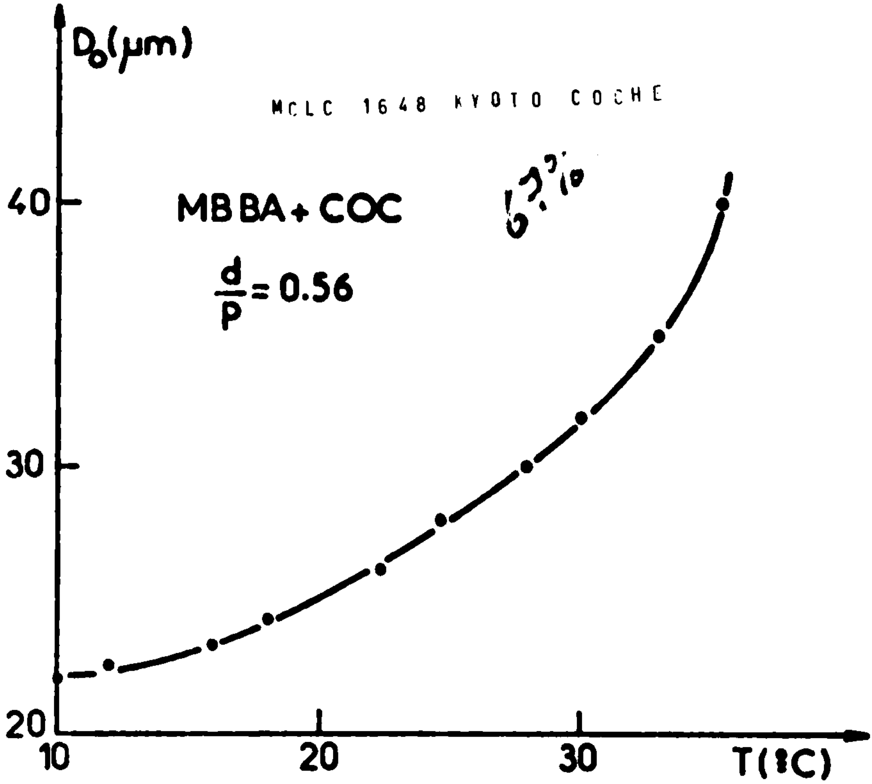
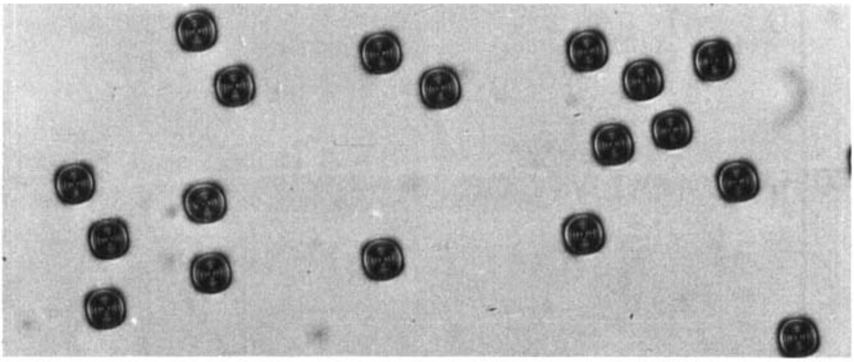


FIGURE 3 Variation of the bubble diameter D_0 *vs.* the liquid crystal temperature *T*.

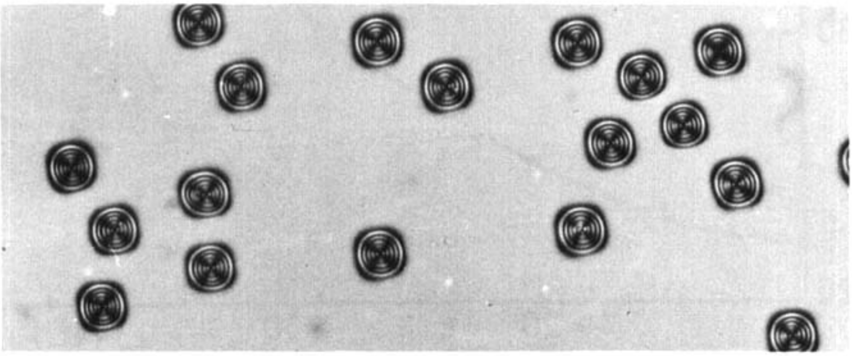
cell is heated. The light transmitted by the texture between crossed polarizers increases with the bubble diameter, therefore with the applied voltage.

5) As mentioned above, the texture can be erased by application of a high frequency ($\approx$ 1 000 Hz) voltage. In fact partial erasure occurs from 500 Hz approximately. We have studied the erasure conditions by determining the number N of bubbles remaining after application of a given erasure voltage during various times t_E. Between successive measurements the texture is completely erased and then reinduced. In Figure 6 the number N is plotted as a function of the time t_E for different values of ratio d/p, frequency and voltage. The time required for complete erasure depends little of the applied voltage and of its frequency but decreases notably when the ratio d/p, therefore the instability of the texture, increases.

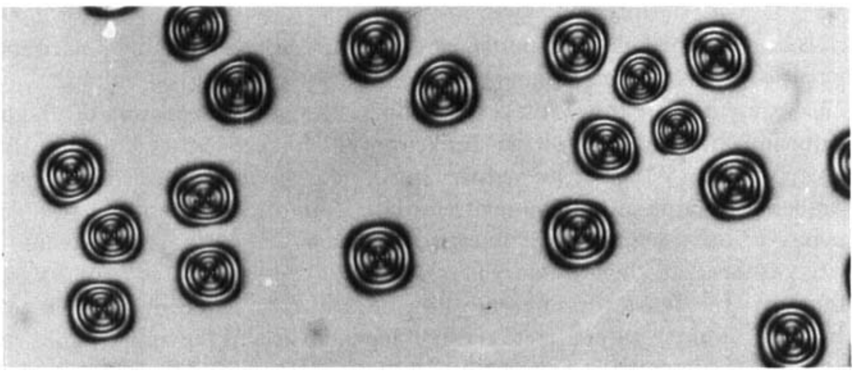
6) Bubble textures can also be suppressed if a magnetic field parallel to the electrodes is applied to the nematic-cholesteric mixture, i.e. which tends to



a



b



c

FIGURE 4 Increase of bubble size by application of an electric field.

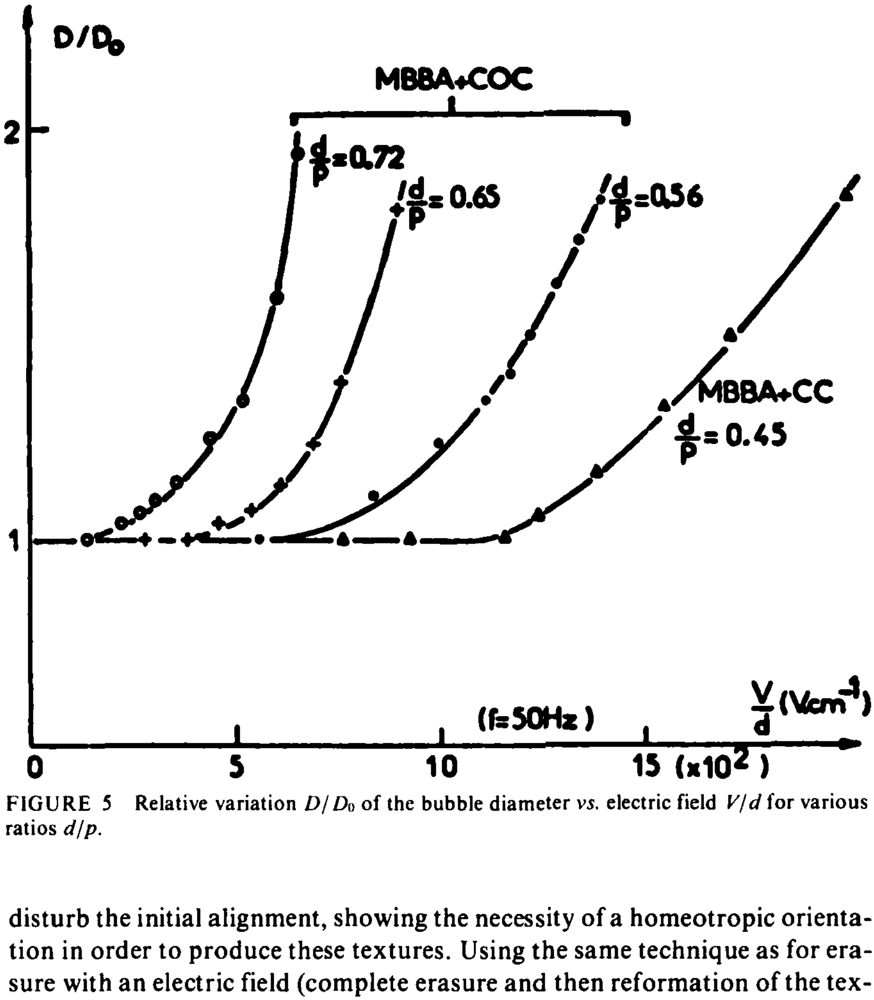


FIGURE 5 Relative variation D/D_0 of the bubble diameter *vs.* electric field V/d for various ratios d/p.

disturb the initial alignment, showing the necessity of a homeotropic orientation in order to produce these textures. Using the same technique as for erasure with an electric field (complete erasure and then reformation of the texture between successive measurements), the number N of bubbles remaining after application of a magnetic field during one minute is determined as a function of the magnetic field intensity (Figure 7). Complete erasure can be obtained by application of the magnetic field during longer periods but this erasure mode is much slower than the previous method.

In conclusion our results in agreement with the measurements of other authors show that the essential characteristics of the bubble texture (bubble size and stability with and without electric or magnetic field) depend strongly on the ratio d/p.

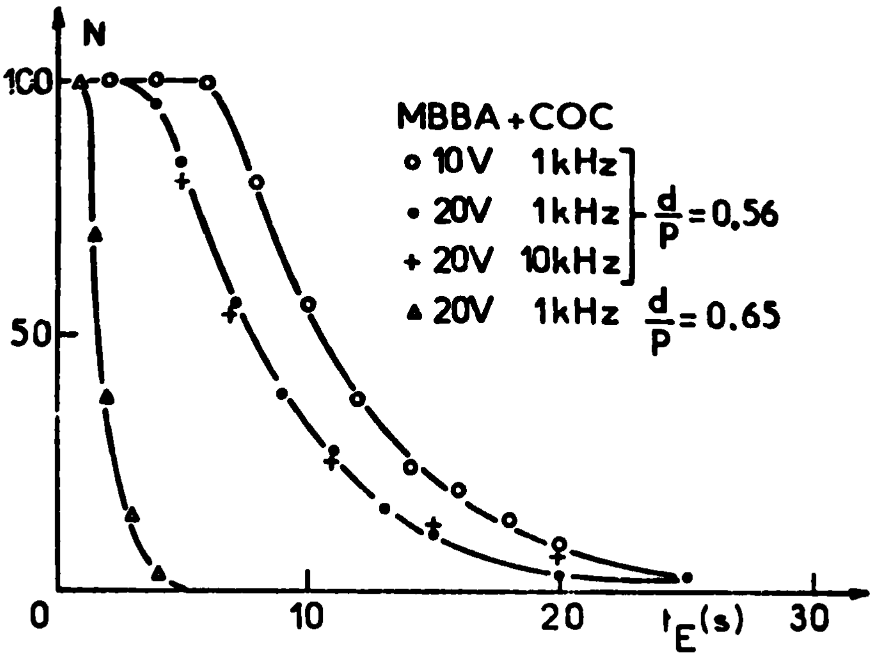


FIGURE 6 Variation of the number N of bubbles remaining after application of an erasure voltage during time lengths t_E in various conditions.

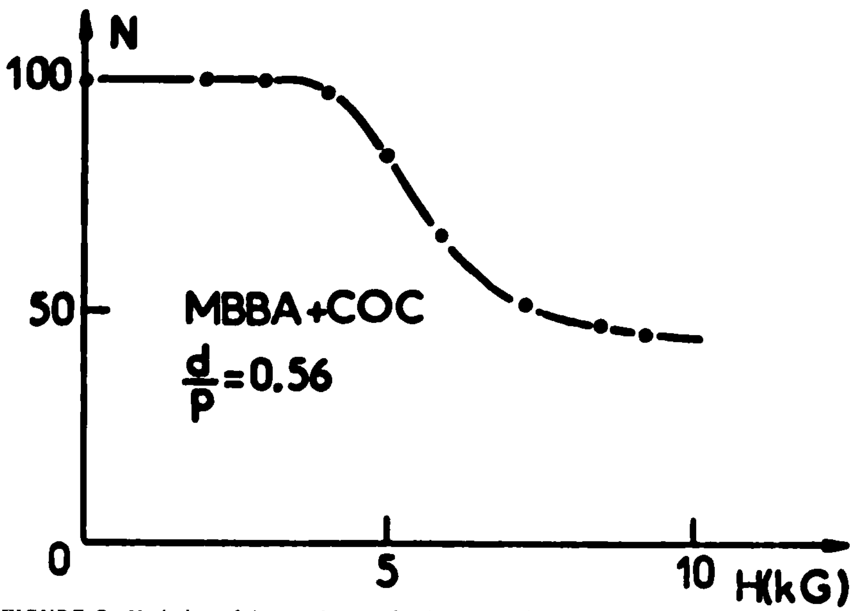


FIGURE 7 Variation of the number N of bubbles remaining after application of a magnetic field *vs.* the field intensity.

Acknowledgments

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