Spiral domains in a nematic liquid crystal

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The spiral domains in a nematic liquid crystal MBBA are observed experimentally.

Thermotropic cholesteric liquid crystals and certain lyotropic liquid crystals are known to form a periodic spiral texture which results from their helical structure.[1] The possible existence in nematic liquid crystals of flexoelectric macroinstabilities in the form of spirals with a double helix was recently predicted theoretically.[2] The necessary condition for the appearance of such instabilities in a nematic liquid crystal with the

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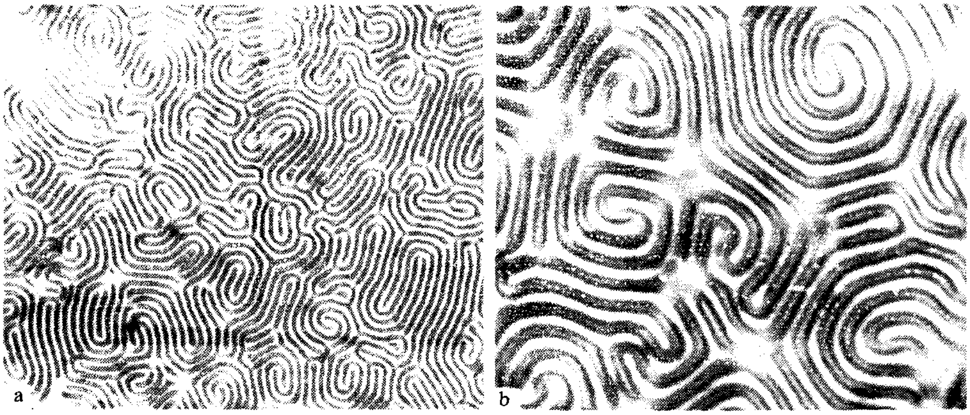

FIG. 1. Spiral domains in a thin layer of MBBA at the surface of a polar cut of gadolinium molybdate. (a) 100× magnification; (b) 450× magnification.

appropriate flexocoefficients in a uniform electric field is that the initial orientation of the liquid crystal be homotropic when it is weakly coupled with the surface of the substrate.

In the present letter we discuss the spiral domains which were observed experimentally in an ordinary nematic liquid crystal 4-methoxybenzylidene-4′-butylaniline (MBBA) with a negative anisotropy of the dielectric constant (Fig. 1). A thin MBBA layer (4–5 μm) is deposited on a freshly prepared polished oblique cut (close to $\perp P_s$) of gadolinium molybdate (GMo), a ferroelectric crystal. The surface of the ferroelectric crystal to be studied forms an angle of $\sim 30'$ with the polar axis of the crystal. The initial orientation of the nematic liquid crystal layer on the polar cut of the crystal is homotropic. The fact that the nematic liquid crystal is weakly coupled with the ferroelectric substrate (the rough edges of nematic liquid drops are shown in Fig. 2) is indicated by the poor wettability of the thin layers of the nematic liquid crystal with the surface of the ferroelectric.

The period of the observable spiral instabilities is on the order of the thickness of the nematic liquid crystal layer ($\sim$4–5 μm). In Figs. 1a and 1b, we see both right- and

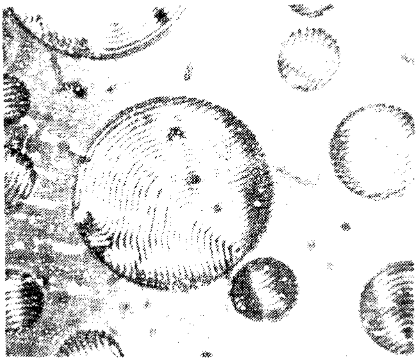

FIG. 2. Nematic droplets at the polar surface of the crystal (the rough edges of the droplets are clearly evident).

left-handed spiral domains, whereas spiral domains in cholesteric liquid crystals can be only of one sign.[2] We notice the faceting of the spiral domains, which suggests that the observable inhomogeneities are closely packed (Fig. 1b). Figure 2 shows the packing of the spiral inhomogeneities in the individual drops of the nematic liquid crystal.

A large number of twist centers in the spiral domains seems to be determined by the imperfections on the surface of the ferroelectric crystal. Domains are formed at random points (at points where the uniform orientation of the nematic liquid crystal is disrupted), which accounts for the irregular arrangement of their centers (Fig. 1a). The center of a spiral domain can have a pair of linear disinclinations.[3] We see that a spiral instability can form if the following condition is satisfied[4]: $2r > d$, where r is the radius of the first turn of the spiral, and d is the distance between the centers of the spirals.

The threshold stress at which the flexoelectric spiral instability occurs in a nematic liquid crystal is independent of the thickness of the layer and is given by[2]

$$U \cong 10 \frac{K}{f_3 + 0.08 f_1},$$

where K is the average Frank constant, and f_1 and f_3 are the flexoelectric coefficients.

The stationary threshold field in which the spiral instabilities are formed in the ~ 5-μm–thick MBBA layer ($f_1 \cong 3\times10^{-4}$ esu/cm, $f_3 = -4\times10^{-4}$ esu/cm, $K \sim 10^{-6}$ dyn) (Ref. 5) is estimated to be $E_f \sim 10^3$ V/cm. The formation of spiral domains in the MBBA layer at the surface of the ferroelectric substrate is evidence that there is a field near the surface of the ferroelectric crystal.[6] At room temperature, the field is on the order of 10^3–10^4 V/cm for a gadolinium molybdate crystal, in satisfactory agreement with the estimated value of the threshold field at which the spiral flexoinstabilities are formed.

We have detected similar spiral macroinhomogeneities in nematic liquid crystals with $\Delta\epsilon > 0$ on the polar surface of a γ-ray irradiated triglycine sulfate ferroelectric crystal. We know that the cleaved surface of this crystal exhibits a homogeneous homotropic orientation of the nematic liquid crystal on the (+) polar surface.[8] The energy that binds a nematic liquid crystal layer to such a surface is[7] $\sim 7\times10^7$ J/m^2, which is several orders of magnitude lower than the orientational energy that binds it to a glass substrate treated according to Shutlen's method. The defective cleaved surface of an irradiated triglycine sulfate crystal can easily form spiral domains. The number of centers that these domains have depends on the irradiation dose of the solid crystal.

Consequently, nematic liquid crystals will have spiral domains if the conditions predicted by Terent'ev and Pikin[2] are satisfied and if the directive surface has defects.

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