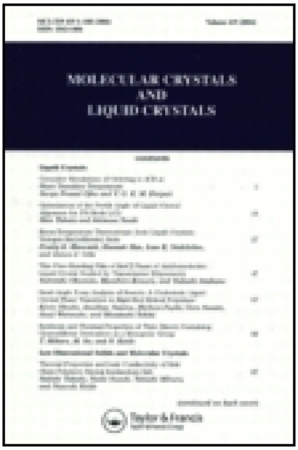

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Pattern Formation in EHC of Planar Nematic Layer with Cylindrical Director Field Configuration

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Pattern formation in planar nematic with cylindrical director field configuration in the conductive regime of electrohydrodynamic convection has been studied experimentally. The rotating roll pattern with axial symmetry has been found above the threshold. For frequency of ac electric field lower than the Lifshitz point, the roll pattern is divided into two systems of rotating oblique rolls so that their superposition looks like *sunflower.* The rotation frequency of rolls has been measured as a function of ac electric field frequency.

Keywords: liquid crystal; electrohydrodynamic convection; oblique rolls; Lifshitz point

INTRODUCTION

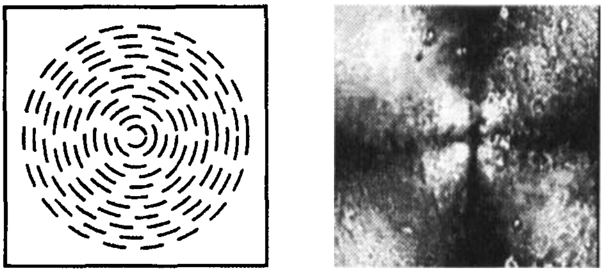
Electrohydrodynamic convection (EHC) in nematic liquid crystal (NLC) has been studied intensively as a subject of pattern formation in anisotropic systems[1-6]. Until now the EHC has been investigated mainly in the planar configuration[6-8] or in the homeotropic configuration[9, 10] with normal orientation of the director **n** on the both plates. For planar alignment (or homeotropic alignment in the presence of a planar magnetic field) the rolls appearing at onset are oriented either normally to the axis of alignment (normal rolls[5]) or oblique to it (oblique rolls[6]). In the latter case, there are two degenerate oblique directions (*zig* and *zag*). For the nematic material MBBA in the planar configurations stationary normal rolls are usually observed[4, 11]. Oblique rolls are observed in some materials below critical frequency, so-called the Lifshitz point[6]. The oblique angle grows continuously below the Lifshitz point, and analysis of the region near this point is an interesting application of the amplitude equation formalism[1]. Besides, the direct transition to travelling rolls via a Hopf bifurcation was found experimentally in thin layers and at high frequencies[4, 12]. Recently, the occurrence of the travelling waves and their linear properties were explained by the weak electrolyte model[7, 13].

Thus, pattern formation in nematics with planar alignment is well recognized now, whereas the EHC instabilities with more complex director field configuration have not been extensively studied. Some experimental results for the case of "hybrid" aligned nematics (the director field interpolates between a normal director alignment on one confining plate and planar director alignment on the other) and planar but twisted director orientation were presented in references[14, 15] respectively.

In this paper, the pattern formation in planar nematic layer with cylindrical symmetry of director field under the action of ac electric field is investigated with polarized-optical microscopy.

EXPERIMENTAL

The experiments were done in a thin layer of the NLC MBBA confined between two SnO_2 coated glass plates. The size of each electrode was 10 mm x 10 mm and the layer thickness was about 20 μm. The measurements were made at the temperature 25±0.2^{0}C. AC electric field was applied across to the nematic layer. The cutoff frequency f_{cutoff} of the sample was at 60 Hz. In order to achieve a uniform circular alignment of the molecules, the electrodes were rubbed by rotating disk with smooth cloth (Fig. 1a). After filling of NLC in a cell the upper and lower electrodes were centered. The microphotograph of nematic layer with such director orientation in crossed polarizers is shown in Fig. 1b. The images of the pattern were obtained by the shadow-graph technique [12].

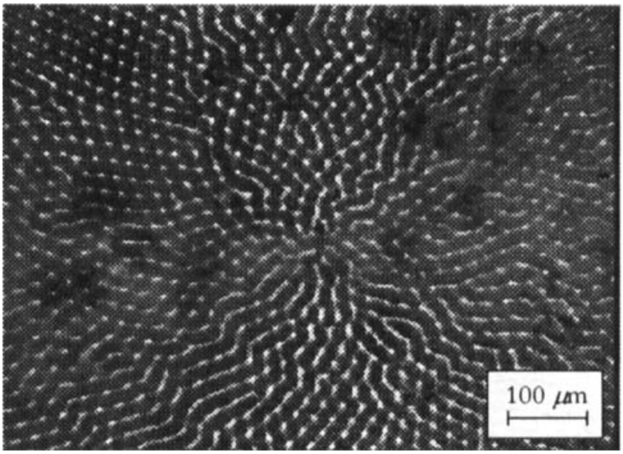


(a) (b)

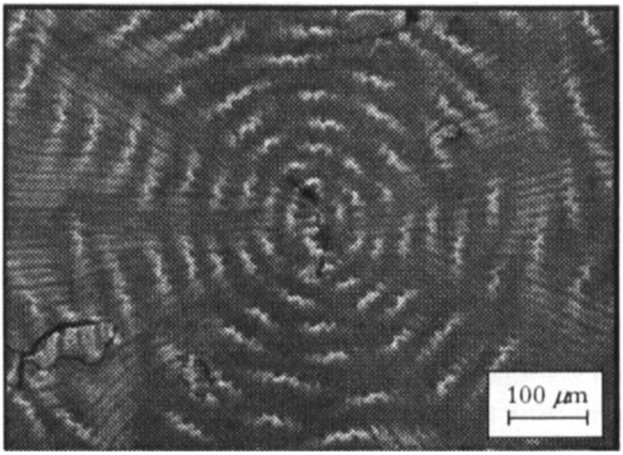
FIGURE 1 Director field configuration in planar nematic with cylindrical symmetry of boundary conditions (a); nematic layer in crossed polarizers (b).

RESULTS AND DISCUSSION

The typical domain patterns that are observed in the EHC of nematics with cylindrical director field configuration are shown in Fig. 2. The rotating oblique rolls of orientation *+6* and *-6*, also called *zig-zag* structure (Fig. 2a), have been found above threshold for frequencies of ac electric field lower than 20 Hz. It has been observed that *zig* and *zag* rotate in the opposite directions and their superposition in some place of the sample looks like *sunflower* grid pattern. With increasing frequency, the oblique angle



(a)



(b)

FIGURE 2 Snapshots of the typical domain patterns: oblique roll regime (a); normal roll regime (b).

decreases and at the Lifshitz point (f_c≈20 Hz) the rolls become normal to the initial orientation of director and arrange radially (Fig. 2b). In this case, roll pattern is essentially differs from the Williams domain, which is observed for the classic planar configuration of director field in the following features: (i) the roll pattern being nonstationary at the threshold that leads to rotation of pattern as a whole around the symmetry center; (ii) due to radial distribution of convective rolls, the domain pattern is divided on the circular zones which are separated from each other by the defects (Fig. 2b). The number of defects grows toward the center.

In order to reveal the streamlines of the flow, small impurities (2-4 μm in diameter) were immersed in the NLC. The observation for these dust particles showed that there was an axial component of the velocity in roll, which was directed to the center of pattern as well as out of it. The axial component of velocity in the rolls (as noted in[15]) may be is caused by twist-effect. In our case, it seems to be also related with weak twist orientation, which is caused by non-coincidence of symmetry centers on the upper and lower substrates.

The threshold characteristics of EHC for this director field configuration were studied both in conductive and dielectric regimes. The frequency dependence of threshold voltage is shown in Fig. 3. With increasing voltage above the threshold, the rolls begin to fluctuate, and the dynamic scattering mode or turbulence occurs with further increasing of the voltage. The rotation frequency of the rolls as a function of ac voltage frequency is shown in Fig. 4. At frequencies f closed to f_{cutoff}, the rotation velocity of roll pattern tends to the saturation.

In the dielectric regime, the radial stripes whose wavelength is much shorter (a few micrometers) than that of the Williams domain (order of the

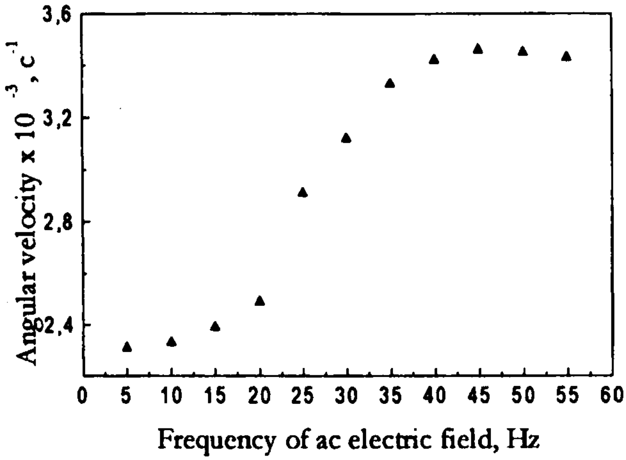


FIGURE 3 Angular velocity of roll rotation as a function of electric field frequency.

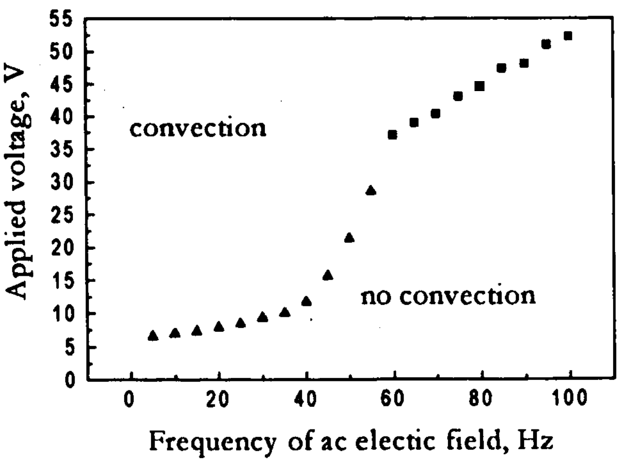


FIGURE 4 Phase diagram for a 20 μm MBBA cell. Conductive (triangle) and dielectric (square) regime of EHC.

thickness of a cell) appear at the threshold voltage and changes into the chevron pattern with axial symmetry which also has many defects.

CONCLUSION

We have carried out the microscopic observation of pattern formation in planar nematic layer with cylindrical symmetry of initial boundary conditions under the action of ac electric field. The results obtained are summarized as follows:

(i) The rotating roll pattern with axial symmetry has been observed above the threshold voltage. The normal rolls transform into *zig-zag* structure at the frequency lower than the Lifshitz point. *Zig* and *zag* rotate in the opposite directions.

(ii) The axial component of director velocity in the roll has been observed experimentally.

(iii) The pattern has many fluctuating defects, density of which increases in the vicinity of the pattern symmetry center.

Acknowledgment

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