ELECTROHYDRODYNAMIC CONVECTION IN PLANAR AND HOMEOTROPIC SYSTEMS OF NEMATIC LIQUID CRYSTALS

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Introduction

When the voltage above a critical value is applied to a thin layer of nematic liquid crystals, the *electrohydrodynamic convection* (EHC) occurs due to their anisotropies of viscosities, dielectric, and elastic constants. This instability, especially in a planar alignment (PA) system, has been studied extensively for the typical subject of the nonlinear-nonequilibrium phenomena [1,2]. On the other hand, less studies in a homeotropic alignment (HA) system have been done so far, because EHC in HA has been thought that it was nothing different from one in PA. But recently some new theoretical predictions have been proposed and they have demonstrated important differences between EHCs in PA and HA by use of computer simulations. Thus EHC study in the homeotropic structure also begins to attract our interests [3-5].

We experimentally investigate the stability and formation processes of convective patterns in PA and HA in this background and try to compare our experimental results with theoretical ones.

Planar Alignment Case

Firstly in PA system, weakly nonlinear aspects can be modeled for example by the Swift-Hohenberg equation and TDGL equation, and in one dimensional system the stability diagram of convective rolls is theoretically obtained from these equations. In the real system, however, it has been difficult to realize the pure one-dimensional situation. Thus, the comparison between theoretical and experimental results in one-dimensional system has not yet done so far.

Here, we tried experimentally to obtain the stability diagram of one-dimensional EHC in PA using a transparent electrode prepared specially by following manners. We used the nematic liquid crystal, MBBA with its parallel conductivity $3.30\times10^{-9}\ \Omega^{-1}\mathrm{cm}^{-1}$ and perpendicular one $2.34\times10^{-9}\ \Omega^{-1}\mathrm{cm}^{-1}$ by doping of TBAB 0.012 wt%. Then it is filled between two glass plates both of which were coated with transparent electrodes. One of them was lithographically etched as a form of stripe in $30\pm2\ \mu$m width and in 1cm length. The layer thickness was chosen as 50μm so as to be one-dimensional systems.

In order to investigate the stability of normal rolls with a given wave number q, the characteristics in EHD was used such that the wave number of normal rolls depend on the applied frequency. First, we prepare normal rolls with a given wave number q by setting the frequency f_1. Then the frequency are changed to the standard frequency f_0 with maintaining the deviation ε from threshold. We call this the frequency-jump method. In this manner we can compulsively prepare the normal rolls with the desired deviation of wave number Q $(=(q-q_c)/q)$,

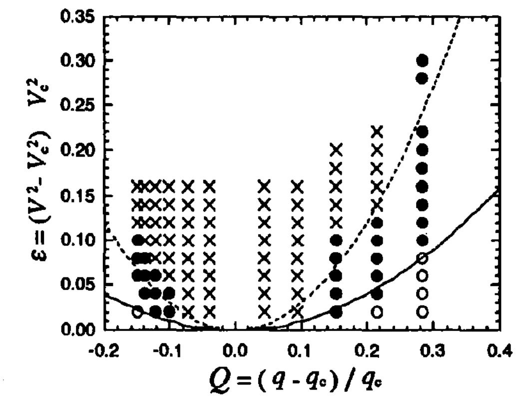

Fig. 1 : Stability diagram of normal rolls in one-dimansional planar system.

and test its stability. Where q_c is a critical wave number at f_0, and in our experiment, f_0 has been chosen as 800Hz. Repeating this procedure for many different values of q, f and voltage V, we can determine the stability range of normal rolls as a function of q and V, i.e. the Busse balloon.

We clarified that the normal rolls state exhibits three kinds of behavior by using this experimental procedure. The first situation is that after a convective pattern entirely disappears new convective pattern with a different wave number appears. The second is that the wave number changes through the annihilation or the nucleation of rolls after the frequency of the applied field was jumped. Thirdly, essentially no change of initial patterns happens for the jump of the frequency of the applied field. These behavior is classified clearly as three areas on the stability diagram as shown in Fig. 1. Open, closed circles and crosses show the first, second and third situation respectively. The two boundaries, such as Neutral and Eckhaus boundary, well agree with the theoretical prediction.

Homeotropic Alignment Case

In a homeotropic alignment system, a very different scenario can be observed for the onset of EHC from the planar configuration. To begin with, the homeotropic alignment becomes unstable at a critical voltage V_f where the director starts to reorient and acquires a planar component. It's called as the *Freedericksz transition.* With further increase of voltage V, a secondary instability leading EHC takes place. The EHC mode with finite wavenumber is superimposed on the Freedericksz mode with zero-wavenumber (the so-called Goldstone mode). Therefore, more richness of phenomena will expected than in the planer case.

First of all, we shall classify the patterns in homeotropic case. We experimentally investigate the phase diagram of a two-dimensional homeotropic system for the applied voltage and frequency. In order to achieve the ideal Freedericksz deformation we used the magnetic field. By applying magnetic field to the sample cell in the x-direction, the uniform tilting of director is set to the x-direction. Therefore, patterns could be classified distinctly and easily analyzed quantitatively.

Fig. 2 shows the phase diagram obtained by the above procedure. Although each pattern in the diagram shows very interesting behavior, the detail will be given in the complete report published in the near future because of limitation of space. However we would like to stress here that the phase diagram was quite different from one of planar case.

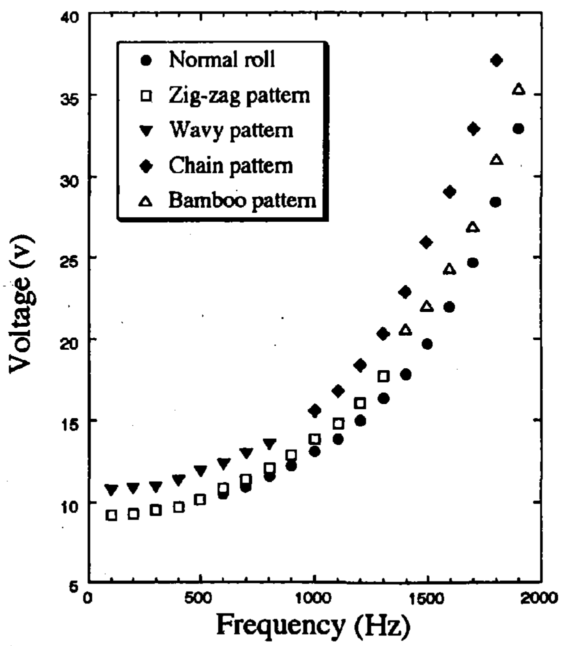

Fig. 2 : Phase diagram of EHC in homeotropic system.

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