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Deformation of the Molecular Orientation of Nematic Liquid Crystals with Homeotropic Alignment in Electric Field

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It is well-known that the thin layer of nematic liquid crystals (NLC) with negative dielectric anisotropy shows the so-called Williams domain pattern at the threshold of an applied electric field, and gives dynamic scattering of light at a higher voltage, while NLC with positive dielectric anisotropy exhibit no such scattering.[1–8] Most measurements on electrically induced hydrodynamic instabilities have been carried out with a molecular orientation in which the long molecular axes of NLC are made to lie parallel to the glass surface, *i.e.*, perpendicular to the direction of an applied electric field.

In this paper we report on the behavior of NLC with homeotropic alignment[9] in the presence of an external DC electric field.

Experimental

Materials. 4-Methoxybenzylidene-4-*n*-butylaniline (MBBA, nematic range 21—41 °C) and 4-(4-*n*-butoxybenzylideneamino)benzonitrile (BBABN, nematic range 63—106 °C). MBBA[10] has a negative dielectric anisotropy ($\varepsilon_{//}-\varepsilon_{\perp}<0$) and BBABN a positive dielectric anisotropy ($\varepsilon_{//}-\varepsilon_{\perp}>0$).[11] The liquid crystal was sandwiched between two transparent tin-oxide-coated glass plates separated by a Mylar spacer about 20 μm thick. Homeotropic alignment of MBBA was achieved by coating a dilute aqueous solution of sodium dodecyl sulfate on the electrode surfaces. Uniform homeotropic alignment was attained by standing the solution for several hours. In the case of BBABN the electrode surfaces were coated with lecithin.[12] Domain patterns were observed under an ordinary polarizing microscope. A sensitive color plate ($R=530$ mμ) was used as the test plate to determine the retardation.

The measurement on light scattering was carried out by use of a He-Ne laser beam polarized through a polarizer and incident normally upon the sample cell. The scattered light from the NLC was passed through an analyzing polaroid and allowed to fall on a photographic film.

The experiments were carried out for MBBA at room temperature and for BBABN at 70—90 °C on the heater regulated.

Results and Discussion

When no electric field is applied, the nematic cell extinguishes the light transmission between crossed polarizers, corresponding to the homeotropic orientation. With the increase in electric field, circular domain patterns are observed at the threshold of the electric field between crossed polarizers (Fig. 1). Both MBBA and BBABN give circular domain patterns, the size of the domain for MBBA being dependent on the state of the electrodes. Each domain shows extinction, cross and quadrants, colored by interference. The first and third quadrants are blue, the second and fourth yellow. These results indicate that the direc-

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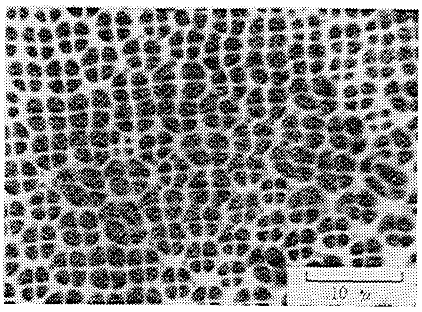

Fig. 1. Photomicrograph of circular domain patterns in MBBA at 2.6 V rms.

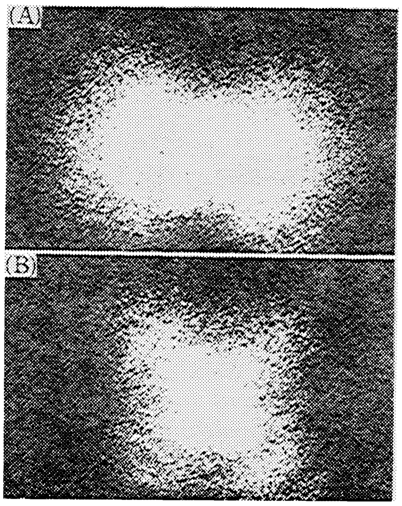

Fig. 2. Light scattering patterns for BBABN at 2.8 V rms with (A) parallel and (B) crossed polarization.

tions of the dipole moments of nematic molecules in the circular domain are arranged as a whole to radiate from the center of the domain.

Figure 2 shows typical light scattering patterns observed slightly above the threshold. The scattering pattern in crossed polars has a four-leaf clover shape which has its maximum intensity at 45 ° to the polarization direction. On the other hand, the pattern in parallel polars is of comparable intensity and has a cocoon-like shape elongated to the polarization direction. The light scattering patterns are associated with the formation of the circular domains, and are similar to those observed in spherulite.[13)]

Heilmeier reported a similar circular domain pattern to that mentioned above using butyl *p*-(anisylideneamino)cinnamate and suggested that its formation can be ascribed to positive dielectric anisotropy of the nematic molecule.[14)] However, the circular domain, as shown above, can be observed in both MBBA and BBABN, independent of the directional relation between the dipole moment and long molecular axis. Thus, we infer that the appearance of the circular domain is due to the homeotropic alignment subjected to the electric field, irrespective of positive or negative dielectric anisotropy of the nematic molecule. It is suggested from both the microscopic circular domain and light scattering pattern that the applied electric field causes an ellipsoidal molecular deformation (Fig. 3).

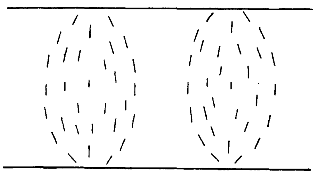

Fig. 3. Schematic representation of molecular orientation corresponding to the circular domains. Solid lines indicate the long molecular axes of nematic molecules.

As voltage is further increased, the circular domain is broken and a turbulent flow takes place. MBBA exhibits dynamic scattering of light, but not BBABN.

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