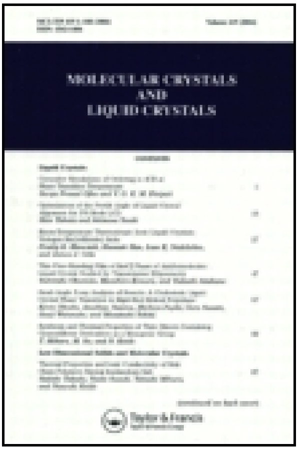

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Magnetic Field Effect on the Alignment of a Discotic Liquid Crystal

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The influence of a magnetic field on the alignment was investigated in the discotic nematic (N_D) phase of a triphenylene derivative. The uniform alignment was achieved when a magnetic field of 5T was applied parallel to the cell surface during the cooling process. The director was perpendicular to the surface when the cell was coated with polyimide alignment layers and parallel when the surface was uncoated.

Keywords: discotic liquid crystal; magnetic field; alignment

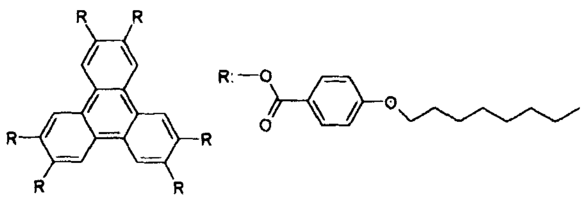
INTRODUCTION

Discotic liquid crystals have attract attention for their high charge carrier mobility and excellent photoconductivity [1]. A typical discotic liquid crystalline molecule has a flat, or nearly flat aromatic core with flexible aliphatic chains. The cores stack up and make columns in discotic liquid crystal phases and this columnar structure yields their attractive optoelectric properties [2,3]. Discotic liquid crystals show a large anisotropy alike other liquid crystals composed of rod-like molecules. It is important to align discotic liquid crystals uniformly not only to make the best use of them but also to understand their intrinsic properties. Till now, some trials such as the uses of surface effect and shear flow were made to obtain uniformly aligned cells of discotic liquid crystals [4-7]. These alignment techniques are indeed useful. However, the shearing technique requires a special cell and the use of surface effect restricts substrates used.

It is well known that rod-like liquid crystal molecules have a positive diamagnetic anisotropy, so that a high magnetic field aligns them parallel to the field. In contrast, typical discotic liquid crystal molecules have a negative diamagnetic anisotropy and also have a tendency to align under a magnetic field [8]. In this paper we will report the effect of a magnetic field on the alignment of a discotic liquid crystal having a triphenylene core structure.

EXPERIMENTAL

The sample used was triphenylene hexa-(4-*n*-octyloxybenzoate), designated as C8OHBT, whose chemical structure and phase diagram are shown in Fig. 1.



Iso. (510.4K) ND (436.5K) Dr (410.8K) Cryst.

FIGURE 1 Molecular structure and phase diagram of C8OHBT.

The sample cells composed of two glass plates and polyimide spacer films of 50, 75 and 125 μm thick. Two types of cell surfaces, uncoated bare glass and coated with polyimide alignment layers (Toray-SP550), were used to examine the combination of the surface and the magnetic field effect. Both cells were not rubbed. The cell was filled with the compound and set in a temperature-controlled oven. The oven was then placed in a bore of a superconducting magnet equipped with a refrigerator (Toshiba, TM-5). The magnetic field inside the bore (diameter 12 cm) could be controlled in the range of 0 to 5T. In this study, the magnetic field of 5T was applied to the sample. We examined two configurations; in geometries A and B, the substrate surfaces were parallel and perpendicular to the field respectively (Fig. 2). The oven was once heated up to 513K so that the sample was melted and became the isotropic phase. Then the temperature was decreased at a cooling rate of 0.05 K/min. The growth of the discotic nematic (N_D) phase was observed during the cooling process under a specially designed long-barrel polarizing microscope. After the whole sample changed to the N_D phase, the oven was removed from the bore and the texture was observed under a commercial polarizing microscope.

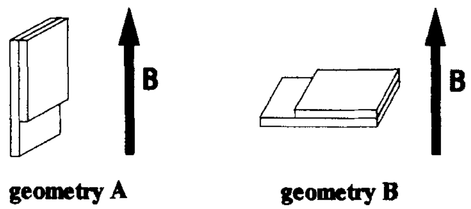


FIGURE 2 Experimental setup of the sample cell and the magnetic field. The substrate surface was parallel to the field in geometry A, and perpendicular in geometry B.

RESULTS AND DISCUSSION

Frst, the texture of the C8OHBT cell cooled without the magnetic field was observed. As the temperature reached the isotropic-N_D phase transition temperature, small spherical domains of the N_D phase appeared in the isotopic matrix. They grew and joined up as the temperature decreased. However, the directions of domains were not uniform and the Schlieren texture was observed both in the uncoated and coated cells at the N_D phase, as shown in

Fig. 3. The results demonstrate that both surfaces do not have ability to align the ND phase uniformly.

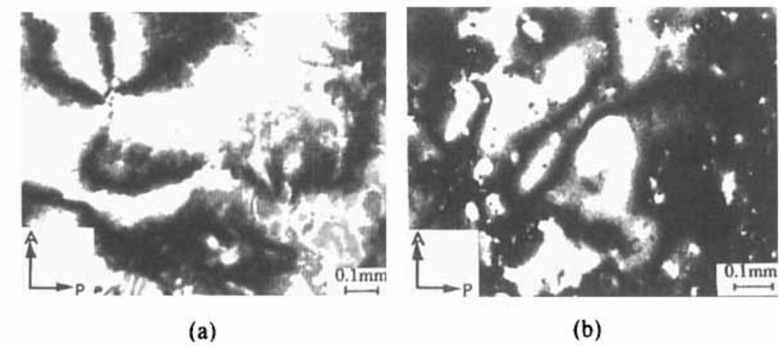


FIGURE 3 The texture of 75-μm-thick C8OHBT cell in the ND phase (475K) cooled in the absence of the magnetic field. (a) The surface was uncoated. (b) The surface was coated with polyimide.
(See Color Plate XX at the back of this issue)

Then the effect of the magnetic field of 5T during the cooling process in geometry A was examined. The application of the magnetic field yielded uniformly aligned cells both in the uncoated and coated cells. In the uncoated cell, the spherical domains appeared alike the cooling process without the magnetic field. However, the domains joined up without making the Schlieren texture. The cell looked uniform and showed birefringence under the polarizing microscope. The extinction direction was parallel or perpendicular to the magnetic field (Fig. 4). Existence of the birefringence suggested that the director was not perpendicular to the surface. To clarify the alignment, the magnitude of the birefringence was determined by the measuring transmittance spectra using a micro-photometer (ORC, TMF-120AFT) with various angles of incidence. The cell was placed between parallel polarizers. The axis of the polarizer was set at 45° with the magnetic field. The magnitudes of the birefringence were evaluated from the transmittance spectrum. Figure 5 shows the birefringence of a 50-μm-thick cell as a function of the incidence angle. Clearly, the birefringence is minimum for normal incidence of light. This result demonstrates that the director uniformly aligns parallel to the surface, *i.e.*, homogeneous alignment.

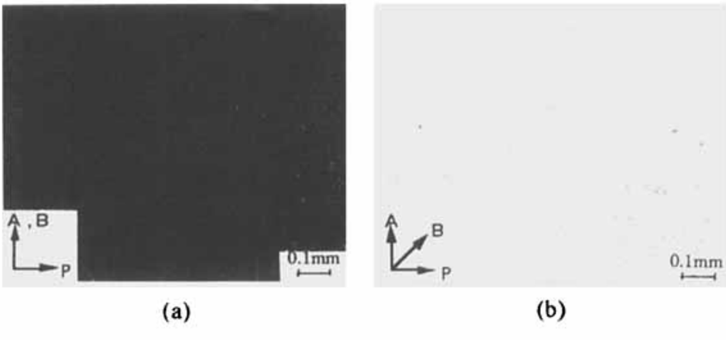


FIGURE 4 The texture of a 75-μm-thick C8OHBT cell, whose surface was uncoated, cooled under the magnetic field of 5T in the N_D phase (475K). (a) Analyzer was parallel to the field. (b) Analyzer was at 45° to the field.

(See Color Plate XXI at the back of this issue)

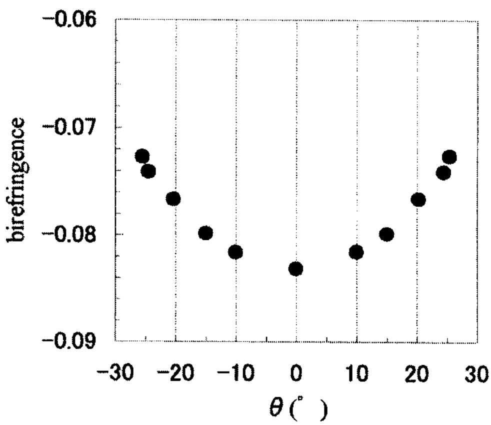


FIGURE 5 The birefringence of a 50-μm-thick cell as a function of the incidence angle.

In geometry B, the Schlieren texture was observed in both the uncoated and coated cells, even when the magnetic field of 5T was applied during the cooling process. Application of the magnetic field was not effective to obtain uniformly aligned cells for the compound in geometry B.

Nematic liquid crystals composed of rod-like molecules tend to align parallel to a magnetic field since their diamagnetic anisotropy is positive. On the contrary, the diamagnetic anisotropy of the C8OHBT molecule is negative and the director tend to align perpendicular to a magnetic field [8]. There exists the freedom of the direction of the director in the plane perpendicular to the magnetic field. Accordingly, only the magnetic field cannot yield a uniform orientation of C8OHBT.

In geometry A, the alignment of the director is restricted in the plane perpendicular to the magnetic field. It seems that uncoated surfaces force molecules edge-on alignment, *i.e.*, the director is parallel to the surface. These two constraints uniquely forces the director align uniformly in uncoated cells. In coated cells, the surface is likely to align the director perpendicular to it and the uniform homeotropic alignment might be achieved without the magnetic field. However, the application of the magnetic field was essential to obtain the uniform alignment. The spherical domains appeared inside the cell probably disturb the alignment of the cell. The application of the magnetic field forces the alignment so that the disturbance becomes negligible.

The alignment of the director is restricted in the plane parallel to the surface in geometry B. The combination of the magnetic effect and the surface effect still leaves the freedom of the alignment in uncoated cells, since both the magnetic field and surface only force the director inside the plane parallel to the surface. Consequently, uniform alignment cannot be expected for uncoated cells. In coated cells, the magnetic field and the surface tended to align the director parallel and perpendicular to the surface, respectively. These two forces conflict with each other and disturb the alignment in the cell.

In conclusion, the usefulness of a magnetic field on the alignment of discotic liquid crystals was demonstrated. The homeotropic and homogeneous alignments were achieved in polyimid-coated cells and uncoated bare glass cells, respectively. The uniformly aligned cells obtained are suitable for measuring the anisotropic properties of the sample.

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