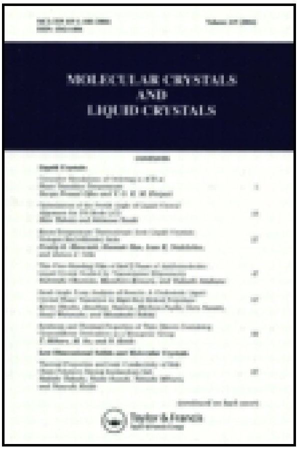

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Tatiana Sergan [a], Milind Sonpatki [a], Jack Kelly [a] [b] & Liang-Chy Chien [a] [b]

[a] Liquid Crystal Institute

[b] Chemical Physics Interdisciplinary Program
Kent State University, Kent, Ohio, 44242

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Polarizing Microscopy of a Chiral Discotic

TATIANA SERGAN[a], MILIND SONPATKI[a], JACK KELLY[ab] and
LIANG-CHY CHIEN[ab]

[a]*Liquid Crystal Institute and* [b]*Chemical Physics Interdisciplinary Program*
Kent State University, Kent, Ohio, 44242

We studied a liquid crystalline compound of disk-like molecules that has a mesophase in the temperature range 104–180° C. The compound exhibits schlieren textures typical to the discoidal nematic phase within this temperature range. Chemical modification of this compound with chiral groups allowed to synthesize a chiral discotic. Incorporating the chiral discotic as a dopant in the discotic compound we produced chiral structures. In the mixtures of chiral and non-chiral discotic, we observed textures typical to rod-like cholesterics: oily streaks, fingerprint textures, and Cano-Grandjean lines in wedge cells. The induced cholesteric pitch was estimated from fingerprint textures. We induced chiral structures with pitch between 10μm and 40μm for the concentration range 1–7 weight % of chiral discotic.

Keywords: discotic liquid crystal; chiral discotic; liquid crystalline textures

1. INTRODUCTION.

Thermotropic liquid crystalline materials are used broadly in various types of electro-optic devices. Most of them utilize rod-like molecules that form calamitic mesophases. The rod-like liquid crystalline molecules possess higher polarizability along the long molecular axis and, thus, form uniaxial media with positive birefringence, featuring $n_e > n_o$, where n_e and n_o are for refractive indices of extraordinary and ordinary wave, respectively. The optic axis of the material is along the ordering direction of the rods. The most commonly used liquid crystal devices are based on a twisted nematic cell placed between two dichroic polarizers. The positive birefringence of liquid crystal layer causes image inversion and undesired interference colors when the device is observed at wide viewing angle. However, these effects can be suppressed by the use of compensation films. To provide full compensation of the liquid crystal layer, an ideal compensation film should mirror the distribution of optic axis in the liquid crystal cell and have negative birefringence $n_e < n_o$. To satisfy these conditions for different liquid crystal cell configurations a number of negative birefringent materials including polymer films and negative crystals have been considered [2-3]. However, the most attractive negative birefringence material is a discotic liquid crystalline film with optic axis distribution matching that one of the liquid crystal cell. For this purpose, the discotic material should be aligned according to the application. The first discotic films used for display compensation had a splayed configuration of the optic axis that was achieved as a result of film fabrication [3]. In this work we have studied a discotic liquid crystalline compound suitable for fabrication of compensation films. This paper is focused on the mesomorphic properties of hexa-alkoxytriphenylenes and presents typical textures of non-chiral and chiral discotic. Chiral discotic films provide compensation for twisted liquid crystal films.

2. MESOPHASES AND TEXTURES OF NON-CHIRAL DISCOTIC.

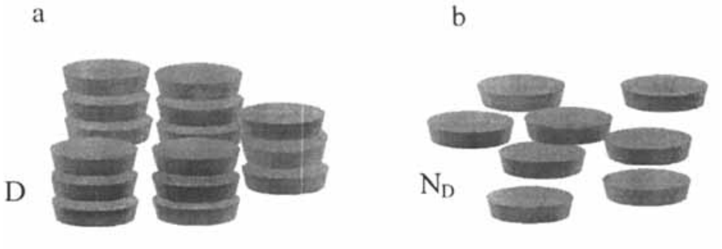

FIGURE 1. Discotic columnar D (a) and nematic N_D (b) phases.

Discotic epoxy monomers and chiral dopant:

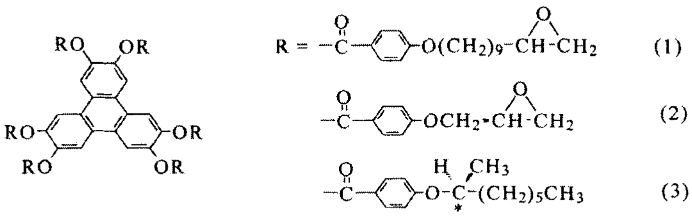

FIGURE 2. Chemical structure of discotic compounds.

Discotic mesophases are usually formed by symmetric, almost flat, coin-shaped molecules that can assemble into stacks (D phases, figure 1 (a)) or layers with no long-range order (nematic-like N_D phase, figure 1(b)) [4-5]. Nematic N_D phases are rare and most of the discotics possess multi-domain columnar textures.

Most discotic molecules possess π-electrons whose conjugation is in the disk plane. The optic axis of these materials is perpendicular to the plane of conjugated π-electrons. Since the refractive index of the compound is related to the electron polarization, these materials possesses a lower refractive index n_e for the light polarized in the direction of optic axis compared to the refractive index for the light polarized in the disk plane n_o. Thus, the material shows negative birefringence $n_e<n_o$.

In our work we studied a discotic compound from the group of 2,3,6,7,10,11 hexa-alkoxytriphenylenes (figure 2 (1)). The functional groups produce a wide temperature range nematic phase $T=104\text{-}180^oC$ (see scanning calorimetry data in figure 3). Within this temperature range, we observed the schlieren texture of the discotic films sheared on a glass substrate (figure 4). If the films are slowly cooled from the

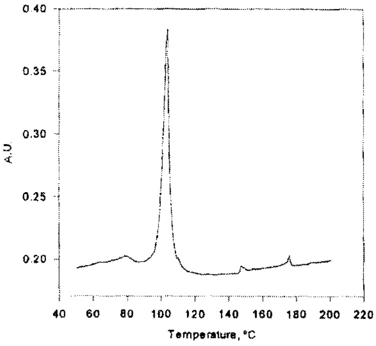

FIGURE 3. Endo-scan of discotic compound.

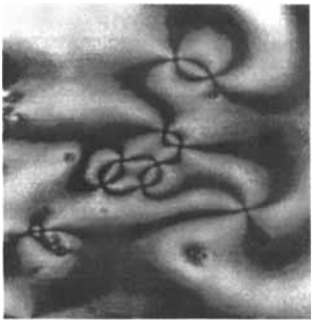

FIGURE 4. Shlieren textures of discotic film on glass.

isotropic phase, the film exhibits a discotic columnar phase that does not show up at the endo-thermal processes. The photograph in figure 4 was taken after material alignment in the mesophase temperature region followed by a rapid quench to room temperature. The film preserves the typical shlieren textures after cooling due to the low viscosity of the material. The nematic state can be also fixed by polymerization of epoxide groups. The image from a polarizing microscope indicates an optic axis distribution within the sample. It appears to be the same as for calamitic phases. However, the sign of the birefringence is opposite comparing to rod-like liquid crystal: studies a using phase compensation plate [6] and refractometry confirmed the negative birefringence of the discotic material.

3. TEXTURES OF CHIRAL DISCOTIC.

We designed a molecule with chiral center by linking a chiral monomer to the side chains of the discotic molecule (figure 2 (3)). This material with chiral centers was used as a chiral dopant for the discotic. We studied mixtures of chiral and non-chiral discotic with the chiral component ranging 1-7%.

To observe textures of chiral discotic we used wedge cells made with glass substrates with rubbed polyimide alignment layers. We used different size (5-100 microns) fiber spacers placed along one of the edges of the substrate to control the wedge thickness. Wedges filled with a mixture of discotic and chiral discotic were heated for 48-72 hours in an oven at T=120° C to achieve alignment. After the alignment process was completed, the samples were cooled to room temperature and observed under a polarizing microscope. We observed typical planar textures and Cano-Grandjean lines in the thin parts of the wedges (figure 5). We have been able to get 2-3 disclination lines.

FIGURE 5. Cano-Grandjean lines in chiral discotic.

FIGURE 6. Oily streaks in chiral discotic.

Because of the weak anchoring, planar textures are not observed in the thicker part of the wedge. Instead, fingerprint textures and oily streaks developed in the thicker regions of the wedges (figures 6 and 7). The figures are essentially of the same type of disclination observed from different directions [1]. As in the case of schlieren textures, polarizing microscopy gives the image of the optic axis distribution in the sample. That is why the discotic demonstrates textures that are similar to the textures of calamitic cholesterics.

The period *p* of the fingerprint texture directly depends on cholesteric pitch *P*: $2p=P$. To estimate the twisting power of chiral discotic dopant, we calculated periods of fingerprint textures developed by discotic with the chiral dopant in the concentration range

1-7%. Figure 8 shows the measured dependence of the inverse of the cholesteric pitch versus concentration C of chiral discotic in weight %. The typical relationship between dopant concentration and induced pitch - $PC=constant$ - for calamitics also holds true for discotics. We estimated the twisting power of the chiral discotic as $\beta = {}^{1}\!/_{PC} \approx 0.018\mu m^{-1}$. Thus, the pure material should demonstrate the selective reflection with maximum at the red or near infrared regions. We did not detect Bragg reflection in cells or films formed from the chiral discotic. To observe the selective reflection, the samples should feature a planar alignment of optic axis with the molecular discs standing on their edges. The samples should be almost mono-domain. However, the conventional types of alignment layers

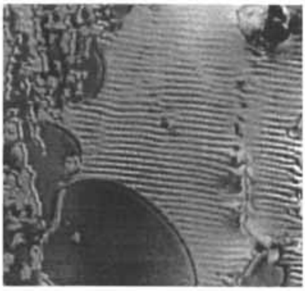

FIGURE 7. Fingerprint texture in chiral discotic.

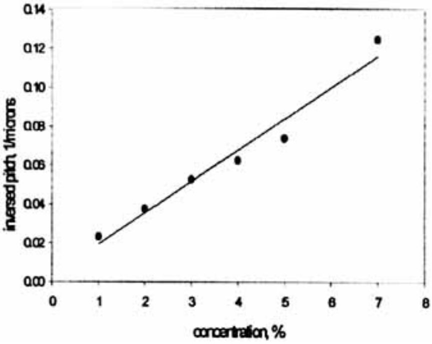

FIGURE 8. Measured inverted cholesteric pitch vs concentration of chiral discotic.

(most polyimides, polyvynyl alcohol and rubbed glass) do not provide the planar alignment of discotics or the alignment is not strong enough to retain a helical pitch. We succeeded with the planar alignment of discotics using chemically modified polyimides; however, even in this case, we have been able to fabricate mono-domain structures with twist angles 90° or less.

4. CONCLUSIONS.

We studied textures of non-chiral and chiral discotics that demonstrated nematic and cholesteric ordering in the temperature range 104-180° C. Textures of these compounds observed under the polarizing microscope are similar to the textures of calamitic molecules because of similarities between the optic axis distributions within the studied phases. We observed schlieren textures in the pure discotic compound typical to nematic ordering in calamitic nematics. We detected disclinations typical for Cano-Grandjean lines, oily streaks and fingerprint textures in the mixtures of chiral and non-chiral discotics that are also typical to cholesterics. The relationship between dopant concentration and induced pitch observed for calamitics, i.e. $PC = const$, also holds for discotics.

Acknowledgements.

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