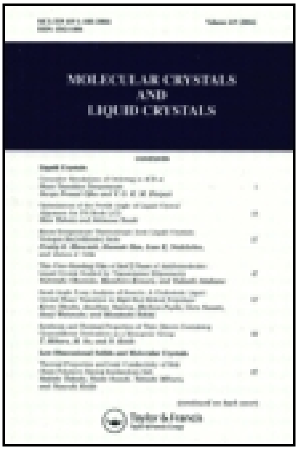

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Physical Parameters of a Fluid Discotic Mesophase

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Physical Parameters of a Fluid Discotic Mesophase

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Freederickz transition in a fluid discotic mesophase of disk like molecules has been investigated.
Some physical parameters of this mesophase, such as birefringence, conductivities and dielectric constants, splay elastic constant K_{11} and viscosity coefficient γ_1, have been measured at various temperatures.

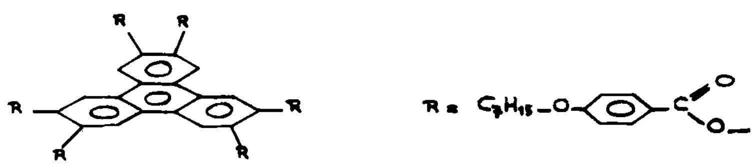
INTRODUCTION

Since the discovery of the first disk-like molecule[1,2] several series have been synthesized[3,4] and some structural properties have been examined by X-ray experiments[5] and optical microscopy.[6]

Magnetic field effects, diamagnetic anisotropy[7] and electrooptic effects[8] have also been studied.

The aim of this paper is to complete the set of interesting physical parameters of a fluid mesophase of a disk like molecule.

The fluid mesophase studied is the hexa-heptyloxybenzoate of triphenylene (H7OBT)[3]



which exhibits the phases:

$$K \xrightarrow[165^\circ C]{} \mathcal{D}_F \xrightarrow[252^\circ C]{} I$$

Freederickz transition has been observed in planar cells. The birefringence Δn, the conductivities and dielectric constants ($\sigma_{\parallel}$, $\sigma_{\perp}$, $\epsilon_{\parallel}$, $\epsilon_{\perp}$), the splay elastic constant K_{11}, and the viscosity coefficient γ_1, have been determined at various temperatures.

EXPERIMENTAL CONDITION

The liquid crystal cell is a thin film of aligned discotic material sandwiched between two glass plates coated with etched transparent electrodes.

The useful area of the cell is 2 cm^2 and a uniform thickness of 25 μm is achieved with polyimide spacers; the effective thickness is controlled by capacitance measurements.

We use this type of material and epoxy bonding in order to work in the discotic temperature range.

Homeotropic or homogeneous alignments are obtained respectively with a surfactant layer such as mellitic acid, or oblique evaporation of silicon monoxide.[6]

This cell is placed in a heating stage (Mettler) under nitrogen flow to prevent a rapid oxidation of the discotic liquid crystal. All these cells are checked with a polarizing microscope.

Birefringence measurements are performed with a standard set up:[9] the cell is placed between crossed polarizers and illuminated with an He Ne laser beam falling at normal incidence; then, the signal is detected with a photodiode.

Birefringence versus voltage curves are obtained by applying an A.C. voltage ramp to the liquid crystal cell.

The dielectric constant and the conductivity of aligned samples are derived from capacitance and resistance measurements, achieved with a Wayne & Kerr bridge working in the 0.5 kHz to 50 kHz range at a constant voltage of 650 mV_{rms}.

The discotic liquid crystal is synthesized in the chemical Laboratory of Thomson CSF.

BIREFRINGENCE MEASUREMENTS

We first checked the sign of the birefringence Δn, which is negative for this $\mathcal{D}_F$ mesophase, by conoscopy observations.

Then we have used the above stated set up to obtain Δn versus temperature. The homogeneous cell has been placed in such a way that its easy axis is at an angle of 45° to the direction of the polarizer.

For a given wavelength λ, the extrema of the transmitted light intensity versus temperature satisfy the relation

$$\frac{e \cdot \Delta n}{\lambda} = m \qquad \begin{array}{l} e = \text{cell thickness} \\ \lambda = 0.603\ \mu\text{m} \\ m \text{ is an integer} \end{array}$$

Hence with this measure and the curves of birefringence versus voltage obtained at various temperature, we get Δn versus T (Figure 1).

We note that this mesophase has a low negative birefringence, constant in a large range of temperature.

DIELECTRIC CONSTANTS AND CONDUCTIVITIES

Resistance and capacitance of homeotropic and homogeneous cells before and after filling in, have been determined.

The dielectric constant is calculated as

$$\epsilon = \frac{C_{lc}}{C_o}$$

and the conductivity as

$$\sigma = \frac{\epsilon_0}{R_{lc} C_o}$$

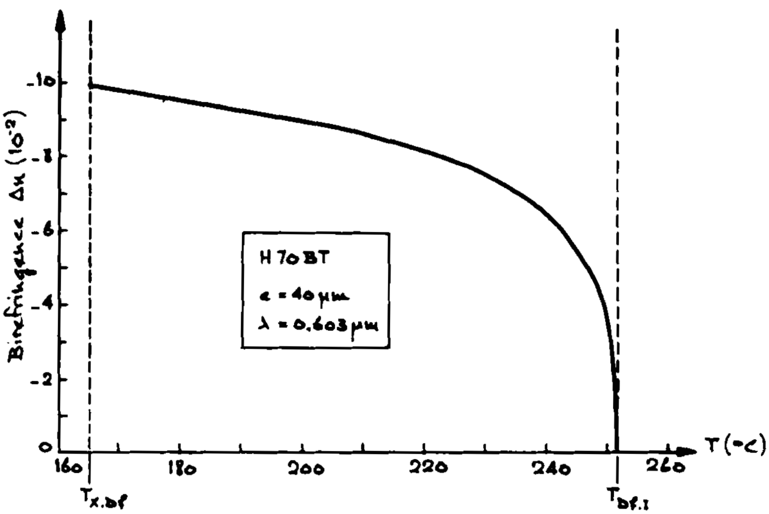


FIGURE 1 Birefringence of H70BT versus temperature.

Where R_{1c} is the measured resistance of the cell, Co and C_{1c} the capacitance of the empty and the filled cell respectively.

At 230°C we have found

$$\epsilon_{\parallel} = (3.78 \pm 0.02)\epsilon_0 \qquad \nu = 20 \text{ kHz}$$

$$\epsilon_{\perp} = (3.33 \pm 0.02)\epsilon_0$$

Figure 2 gives the values of $\epsilon_{\parallel}$ and $\epsilon_{\perp}$ at various temperature.

In the low frequencies range, ($\nu \leqslant 2$ kHz) a sharp increase of ϵ is observed. This behavior could be explained by introducing an electrode capacitance assumed to be the capacitance of a double layer of ionic impurities. The presence of impurities is moreover confirmed by the high conductivity of the compound.

This phase has a positive conductivity anisotropy and we have measured at 230°C:

$$\sigma_{\parallel} = (6.1 \pm 0.1) \times 10^{-6} \ \Omega^{-1}m^{-1} \ \nu = 20 \text{ kHz}$$

$$\sigma_{\perp} = (4.0 \pm 0.1) \times 10^{-6} \ \Omega^{-1}m^{-1}$$

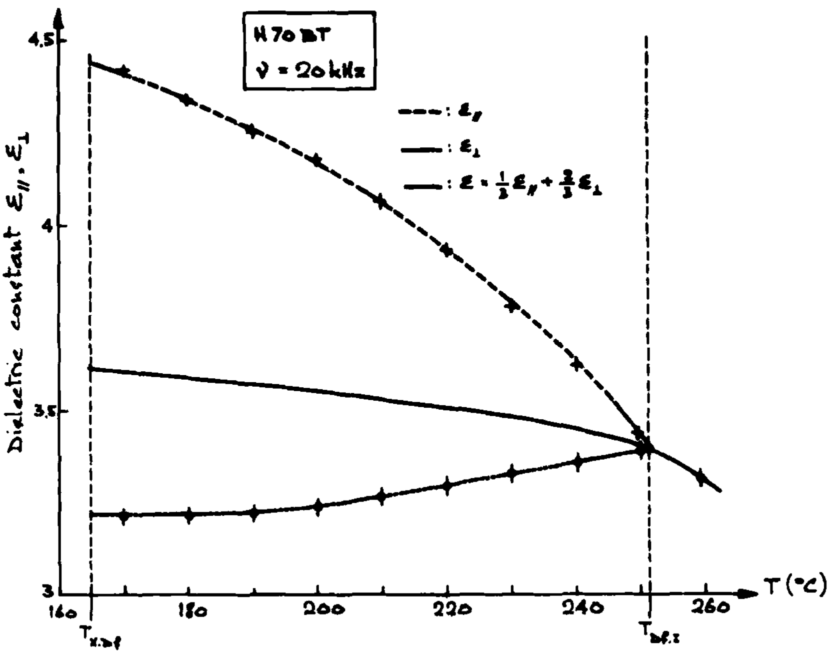


FIGURE 2 Dielectric constants of H70BT versus temperature $\epsilon_{\parallel}$ and $\epsilon_{\perp}$ refer to the value along and perpendicular to the optics axis, ϵ the average value.

these conductivities increase with temperature and, at 255°C, in the isotropic phase, we measured

$$\sigma_i = (8.0 \pm 0.5) \times 10^{-6}\ \Omega^{-1} m^{-1}.$$

ELASTIC CONSTANT OF SPLAY

In order to get the splay elastic constant of this positive dielectric anisotropy $\mathcal{D}_F$ mesophase (K_{11}), we have observed the Freederickz transition of homogeneous cells under an electric field.

The set up used for Δn measurement has allowed us to plot birefringence versus applied voltage at various temperatures. The threshold voltage, we derived from these curves, is related to K_{11} by the well known equation

$$K_{11} = \frac{\epsilon_0}{\pi^2} \epsilon_a V_{th}^2$$

where

$$\epsilon_a = \epsilon_{\parallel} - \epsilon_{\perp}$$

typically, at 230°C we have got

$$V_{th} = 3.5 \pm 0.2\ V_{rms}$$

which gives:

$$K_{11} = (3.5 \pm 0.5)\ 10^{-12} \mathrm{N}.$$

Figure 3 shows all the values of K_{11} computed from the experimental results of ϵ_a and V_{th}. We observe a continuous decrease of K_{11} in the whole $\mathcal{D}_F$ temperature range and note that the value of K_{11} are of the same order of magnitude as the common nematic ones.

VISCOSITY COEFFICIENT

Viscosity coefficient has been measured from the decay time t_d, of the Freederickz transition under an electric field.

This time is given by the following relation[10]

$$t_d = \frac{\gamma_1 e^2}{\pi^2 K_{11}}$$

where γ_1, is the viscosity coefficient, K_{11} the elastic constant of splay, e the thickness of the cell.

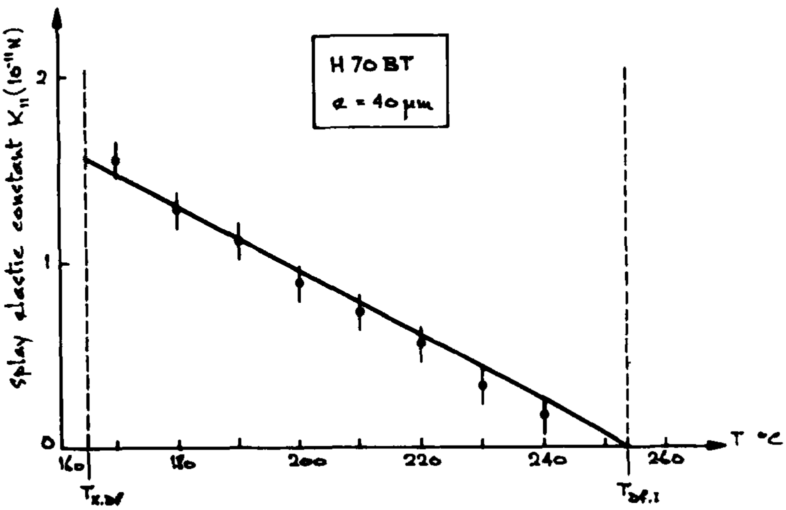


FIGURE 3 Splay elastic constant of H70BT versus temperature.

A 20 kHz modulated pulse has been applied on the planar cell and the variation of the transmitted light intensity through the preceding set up has been recorded by a storage oscilloscope.

At 230°C:

$$t_d = 5.0 \pm 0.1 \text{ s}$$

which gives with previous results of K_{11} and e

$$\gamma_1 = 3.5 \pm 0.5 \text{ Poise.}$$

We note that this value is higher, by one or two decades than common nematic ones.

The mesophase has a very high viscosity which can be explained by the shape of the disk like molecules.

CONCLUSION

Freederickz transition in a $\mathcal{D}_F$ mesophase with $\Delta\epsilon > 0$ has been investigated and has allowed us to measure the splay elastic constant.

The main features of this discotic compound are:

—a low negative birefringence

—a splay elastic constant of the same order of magnitude as that common nematic materials

—a high viscosity which seems to be a characteristic of the $\mathcal{D}_F$ phase.

From the electric point of view, this $\Delta\sigma > 0$ and $\Delta\epsilon > 0$ compound has a high conductivity owing to the high temperature range.

Such $\mathcal{D}_F$ phase can be interesting for display applications if we get a compound at room temperature.

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