DISTORTION OF A TWISTED NEMATIC LIQUID CRYSTAL BY A MAGNETIC FIELD

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The critical magnetic field H_c for distortion of a twisted nematic structure is measured as a function of the sample thickness d. Except for values of $d < 10$ μm the product $H_c \cdot d$ is constant, in agreement with the theoretical predictions by Leslie.

A thin layer of a nematic liquid crystal can be twisted either by rotating one of the glass plates in its plane [1] or by previously rubbing of the two glass plates in different directions [2]. Recently Leslie discussed these helical structures theoretically [3], including the effect of a magnetic field parallel to the helix axis of the twisted nematic layer. For a reasonable twist angle $2\phi_0$ and $\chi_{\parallel} > \chi_{\perp}$, a threshold field H_c is predicted at which the molecules begin to rotate. $\chi_{\parallel}$ and $\chi_{\perp}$ are the magnetic susceptibilities parallel and perpendicular to the molecular axis. H_c is given by

$$(\chi_{\parallel} - \chi_{\perp}) H_c^2 d^2 = k_{11} \pi^2 + (k_{33} - 2k_{22})(2\phi_0)^2 \qquad (1)$$

d is the film thickness; k_{11}, k_{22} and k_{33} are the elastic moduli. For $H > H_c$ untwisting occurs.

This letter reports some results for the threshold field H_c which is measured as a function of d for $2\phi_0 = \pi/2$. Eq. (1) then predicts that $H_c \cdot d$ is constant. The twisted structure was obtained by rubbing two glass plates covered with a conducting transparant SnO_2 layer in perpendicular directions. The nematic liquid crystal was N-(p-methoxybenzylidene)-p-n-butylaniline (MBBA). The resulting pitch is much larger than the wavelength of visible light. Therefore, the polarisation plane of linearly polarised light travelling through the twisted nematic layer at normal incidence rotates through the twist angle. Due to the anisotropy in the dielectric constant small changes in the orientation can easily be detected by capacity measurement. For MBBA we found $\epsilon_{\parallel} = 4.95$ and $\epsilon_{\perp} = 5.26$. These values are slightly different from those reported by Diguet et al.[4] which can probably be attributed to impurities. The capacities were measured at a frequency of 1592 Hz with a Wayne and Kerr universal bridge B221.

The actual layer thickness was obtained from capacity measurements of the empty cell, the cell filled with the twisted nematic ($\epsilon = \epsilon_{\perp}$) and with the untwisted nematic at $H \gg H_c$ ($\epsilon = \epsilon_{\parallel}$). Fig. 1 gives the relative changes in the cell-capacities ($\Delta C/C_0$) as a function of the magnetic field H parallel to the helix axis. For $d = 106$ μm the saturation value of $\Delta C/C_0$ at $H \gg H_c$ is about 0.085. This is in good agreement with the theoretical value $(\epsilon_{\perp} - \epsilon_{\parallel})/\epsilon_{\perp} = 0.080$. We find smaller saturation values for smaller values of d, which can be attributed to wall effects that become relatively more important.

Expression (1) for H_c is obtained as the first term in a series expansion and is only valid for values of the maximal distortion angle ϕ_m close to zero. Thus, the intersection of the $\Delta C/C_0$ against H curve with the H-axis gives the value of H_c. In practice it was found difficult to determine unambiguous values of H_c in this way, so H_c was determined rather arbitrarily as the field at which $\Delta C/C_0$ is 0.1%. However, the conclusions are also valid for other choices, e.g. 0.5 or 1%. The results are given in table 1. Within accuracy of the measurements the values for $H_c \cdot d$ are constant except for $d = 7.2$ μm where the $H_c \cdot d$ product is much smaller. This indicates that the theoretical model is valid unless very thin layers (< 10 μm) are considered.

Table 1
The magnetic threshold field H_c and the product $H_c \cdot d$ as determined from fig.1.

d (μm)	H_c (kOe)	$H_c \cdot d$ (kOe · μm)
7.2	3.38	24
13.2	3.01	40
30	1.36	41
54	0.85	46
106	0.45	48

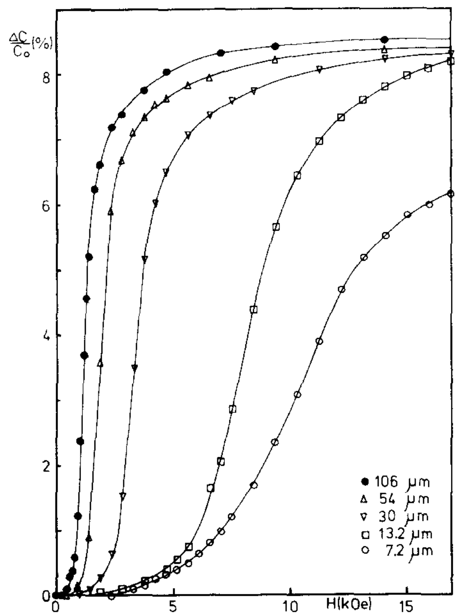

Fig.1. Relative changes in the capacity of a twisted MBBA layer as a function of the magnetic field ($T = 23\,^{\circ}C$).

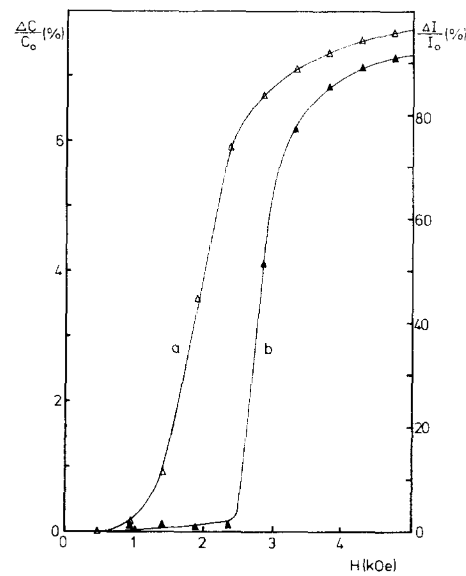

Fig.2. Relative changes in the capacity $\Delta C/C_0$ (plot a) and in the intensity of transmitted polarized light $\Delta I/I_0$ (plot b) as a function of the magnetic field (54 μm sample).

Additional information about the untwisting by a magnetic field can be obtained from optical measurements. Untwisting of the structure gives a decrease in the intensity of light passing through the sample placed between two crossed polarizers. For $H \gg H_c$, when the alignment is almost complete, the decrease in intensity is about 100% since the polarization plane is no longer rotated. In fig. 2 the effect of a magnetic field on the intensity is shown for one of the samples ($d = 54\,\mu$m). The jump in $\Delta I/I_0$ is found at a field that is about 50% higher than the one for $\Delta C/C_0$. So alignment of the molecules in a direction parallel to the applied field occurs to a large extend *without untwisting* the nematic structure.

Untwisting can also be realized by alignment in an electric field parallel to the helix axis. A critical field E_c comparable to H_c can be found for a nematic material with $\epsilon_{\parallel} > \epsilon_{\perp}$. However, the measurement of E_c may be obscured by alignment due to electrodynamic effects [5, 6]. Recently untwisting in electric fields was reported by Schadt and Hefrich [7] for N-(p-ethoxybenzylidene)-p-aminobenzonitril (PEBAB). However, the critical voltage found for PEBAB is equal to the voltage where cellular flow (domains) appears [8]. So the same voltage threshold is found for $2\phi_0 = 0$ [8] and $2\phi_0 = \pi/2$ [7]. Moreover, in MBBA ($\epsilon_{\parallel} < \epsilon_{\perp}$) we also observed untwisitng at the threshold voltage for domain formation completely equivalent to the case of PEBAB where $\epsilon_{\parallel} > \epsilon_{\perp}$. We conclude that Leslie's theory cannot be applied to the experiments of Schadt and Helfrich because the alignment is due to electrodynamic effects.

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