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G. Heppke [a] & F. Oestreicher [a]
[a] Institut für Anorg. u. Analyt. Chemie der Technischen Universität Berlin, D-1000 Berlin 12, Germany
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DETERMINATION OF THE CHOLESTERIC SCREW SENSE

G. HEPPKE and F. OESTREICHER
Institut für Anorg. u. Analyt. Chemie der Technischen Universität Berlin, D-1000 Berlin 12, Germany.

If a cholesteric liquid crystal is placed between a glass plate with planar alignment and a spherical lens with concentric surface alignment, a double spiral disclination line appears. The spiral rotation sense depends on the helix screw sense of the cholesteric phase and the radial distance between the disclination lines on the pitch magnitude. A theoretical calculation of the form of the spiral disclination lines is given and compared with experimental results.

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To fully characterize the helix structure of a cholesteric liquid crystal, the pitch magnitude as well as the screw sense must be known. The screw sense is normally determined either by examining the transmission and reflection characteristics of the cholesteric mesophase in the infrared or visible spectrum (1-6) or by comparison with a cholesteric phase of known screw sense using the contact method (7,8).

In this paper we would like to describe a new and simple method whereby the screw sense may be determined and photographically documented, also allowing the pitch magnitude to be directly measured. It is a modification of the Grandjean-Cano method, which is based on the observation of the disclination lines occurring in a wedge shaped cholesteric sample with homogeneous planar boundary conditions (9,10).

Using a spherical lens (radius R) on a glass plate, it can be shown that the radius r of the disclination rings is a function of the angle between the alignment directions of the lens and the glass plate. If a positive sign is associated with a right-handed helix, then (11)

$$r^2 / 2R = (n - 1/2 + \mathrm{sgn}(p)\,\varphi/\pi)\ |p| / 2$$

$$n = 1, 2, 3 \ldots \qquad \text{Eq. (1)}$$

The helix screw sense can easily be determined by turning the lens through $\pm 80^{\circ}$ for example, producing an increase or decrease of the disclination ring radius depending on the sign. However, by turning the lens the ring system is sometimes destroyed, especially when the helix pitch is small (12). The method described in this paper enables this disadvantage to be avoided in that the lens is provided with a concentric planar surface alignment e.g. by pressing the rotating lens against a cellulose pad. For such boundary conditions it can be shown that:

$$r = (Rp\,\varphi/\pi)^{1/2} \qquad \text{Eq. (2)}$$

where φ, as in equation 1, is measured from the direction of the molecule orientation at the glass plate. Equation (2) describes a double spiral, which is plotted in figure (1) for a right-handed helix ($p > o$). As shown by equation (2) for a left-handed helix ($p < o$) the angle φ must also be negative and consequently the double spiral changes its sense of rotation. Thus the helix screw sense can be immediately obtained from the form of the disclination lines and the pitch magnitude, as in the conventional Cano method, from the radial distance between the lines.

The nematic phase ROTN 403 (Hoffmann la Roche), a commercial liquid crystal mixture, with the addition of the chiral compound CB 15 (BDH) or alternatively ZLI 811 (MERCK) to induce cholesteric structure, was used to experimentally verify the above method. The disclination lines, observed at room temperature using a polarization microscope, are reproduced in figure (2) and (3). From these it can easily be seen that with CB 15 a right-handed whereas with ZLI 811 a left-handed helix is formed. The pitch magnitude can be determined by inserting values from the disclination line radii for an arbitrary angle φ into equation (2) or by determining the scaling factor necessary so that the experimental and theoretical spirals correspond in sense as well as size.

As can be seen from figures (1) and (2) the positions of the disclination lines, calculated using formula (2), are almost identical with the experimental results - however it is not possible to experimentally follow the lines for very small values of r. This mav be caused by inadequate boundary conditions and surface roughness but even under ideal conditions it is not to be expected, that the disclination lines are continuous through the zero point. For a pure nematic phase with the specified boundary conditions, a straight disclination line is to be expected according to formula (2) and this was actually observed running parallel to the direction in which the glass plate was rubbed.

The method of direct determination of the helix rotation sense, as described in this paper, can be used not only for induced cholesteric phases with relatively large pitches but also for pure cholesteric compounds (e.g. ZLI 996, $p \approx -0.5\ \mu m$). Due to the simplicity and ease with which documentary photographs can be produced, the method is especially suitable for repetitive work e.g. the investigation of the correlation between the absolute configuration of chiral molecules and the sense of the cholesteric phases induced by them (6,8,11,13-15).

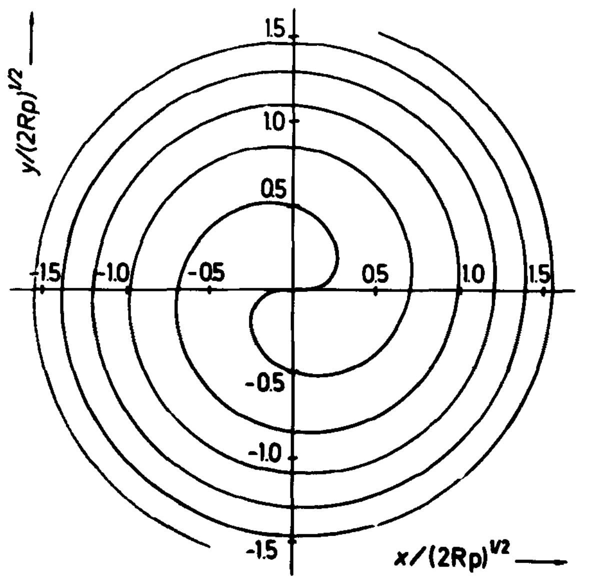

FIGURE 1

Plot of the disclination lines for a right-handed cholesteric phase, calculated using formula (2).

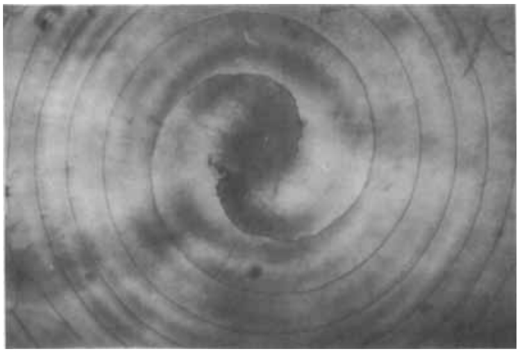

FIGURE 2

Disclination lines for a right-handed cholesteric phase (2.16 wt.-% CB 15 in ROTN 403, p = 9.49 μm, R = 27 mm, t = 23 ^{o}C). The enlargement factor is adjusted to figure (1), so that the spirals of figure (1) and (2) are of equal size.

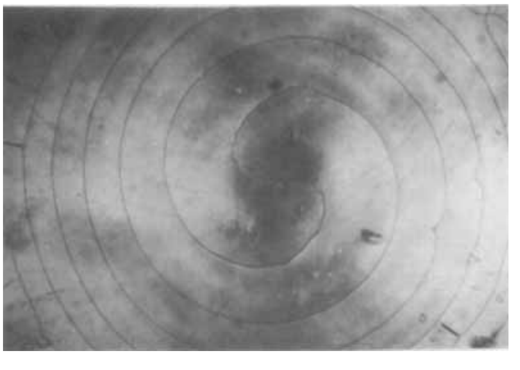

FIGURE 3

Disclination lines for a left-handed cholesteric phase (1.02 wt.-% ZLI 811 in ROTN 403, p = 10.0 μm, R = 27 mm, t = 23 ^{o}C).

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