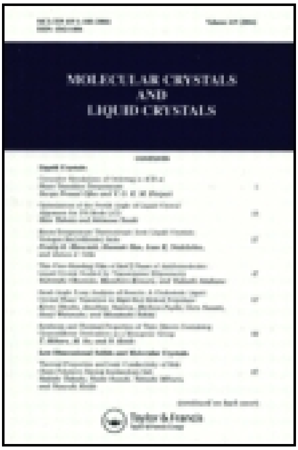

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Observation of High Strength Defect in a Free Standing Film of Ferroelectric Liquid Crystal

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When a free standing film of ferroelectric liquid crystal was cooled from smectic A phase to its ferroelectric phase in the presence of a rotating electric field applied along the smectic planes, we observed a stable high strength disclination in the Sc* phase. This disclination is characterized by eight 'brushes' in the texture, when observed under a polarizing microscope. Even after removal of the electric field the high strength disclination remains stable.

INTRODUCTION

Smectic C liquid crystal phase is a layered structure of long molecules. Within the layers the molecules have short range positional ordering, but they are uniformly tilted with respect to the layer normal. The projection of the molecules onto the layer plane is defined as the C-director. If the phase is made of chiral molecules then they form chiral smectic C (Sc*) phase. This phase exhibits ferroelectricity[1].

The discontinuity in the C-director gives rise to disclinations in the smectic C and Sc* phases. These defects are analogous to the schlieren texture formed in the nematic liquid crystals[2] . However, the C director being a polar vector, the disclinations in the smectic C phase can be characterized by integer number for the topological index 'S'. Disclinations of strength ±1 are commonly observed in the smectic C and Sc* phases in the bound samples. Few reports on the observation of high strength disclinations can be found in the literature. High strength disclinations in nematic liquid crystals have been reported in two component systems[3-6]. Viney et al[6] have observed transient disclinations of strength ±3/2 in the nematic phase of a single component thermotropic liquid crystal of rod shaped molecules.

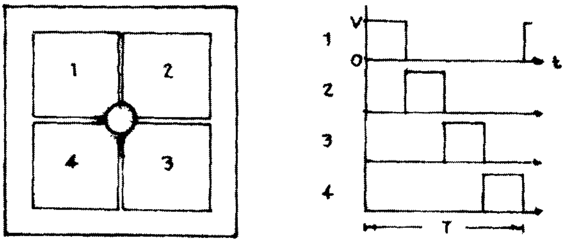

Figure 1: (a) The schematic diagram of the sample holder. (b) The pulse profiles and the phase relationship of the voltages applied at the four electrodes. One complete cycle for electrode - 1 has been shown.

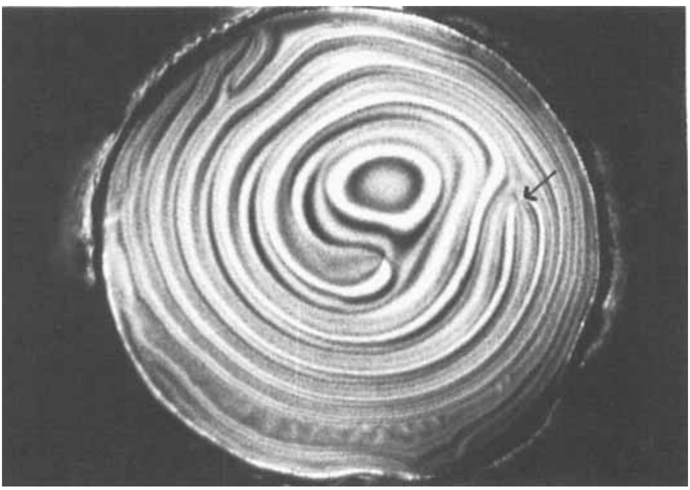

Figure 2: The micrograph of the film in the Sc* phase just below smectic A — Sc* transition, observed between crossed polarisers, showing co-existence of a +2 strength disclination and a target pattern. The +2 strength disclination that is circulating with the applied electric field is shown with an arrow (→).

Authors in[4,5] have reported disclination of strength ±3/2 and ±2 in the mixture of rod like nematogens and plate like non-mesogenic molecules. To our knowledge high strength disclinations (S > 1) in the Sc* phase have not been reported so far.

Formations of different types of structural defects in freely suspended liquid crystal films have been a subject of extensive studies[7-12]. In such films, the weak molecular interactions can be revealed that are suppressed by the influence of the substrate in the bound samples. For this reason, the free standing films can exhibit various thermodynamically stable modulated structures. These structures can easily be influenced by application of electric or magnetic fields. The effects of application of a rotating electric field on the free standing smectic C and Sc* liquid crystal films have also been studied[13,14]. The 'target' and 'spiral' are quite well known patterns formed in smectic C and Sc* free standing films under rotating electric field.

In this paper we report the observation of a +2 strength disclination formed in the Sc* phase of the freely suspended film. The defect is created when the film is cooled from smectic A phase to the Sc* phase in the presence of a rotating electric field.

EXPERIMENTAL

The study was carried out on BDH SCE5, which is a room temperature ferroelectric liquid crystal. The transition temperatures of the material were measured using a locally fabricated heater, and are as follows:

Sc* — 74° — smectic A — 104.8°— cholesteric — 136° — Isotropic

The sample holder consists of a 0.5 mm diameter hole, surrounded by four electrodes as shown in Figure 1(a). The electrodes were connected to a specially designed electronic circuit that generates sequential square voltage pulses as shown in figure 1(b) producing a rotating electric field along the sample area. The rotation time period (T) in the range of 40 micro second to a few seconds (i.e. rotation frequency up to 25 kHz) and the voltage pulse height (V) of up to 300 V were employed in these experiments.

The sample holder was heated above the Sc* — smectic A phase transition using the heater. A free standing film of the material was formed on the hole of the sample holder in the smectic A phase. The observations were made using Lieca DM LP transmission polarizing and Lieca DM LM reflected light microscopes. In our experiments the film had a thickness of 500-800 nm. The perfect black colour of the film in the smectic A

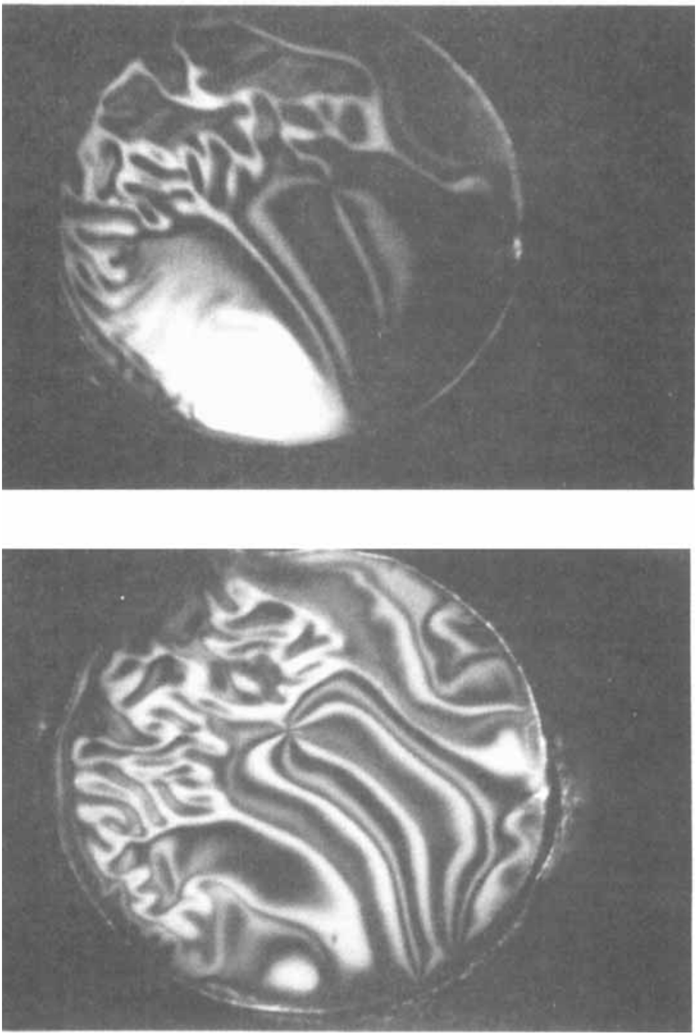

Figure 3: The micrograph of the free standing film obtained in the absence of rotating electric field. The sample was illuminated with white light. (a) The film observed with crossed polarisers. (b) The same disclination observed with crossed polarisers rotated at 45° with respect to the sample. As we rotate the polarisers, the 'brushes' also rotate in the same direction indicating positive disclination.

phase, as viewed between the crossed polarisers in the transmission mode, indicated the homeotropic alignment of molecules in the film.

RESULTS

The sample was cooled to the Sc* phase in the presence of an electric field produced by a voltage pulse of height 47 V circulating at the frequency of 1 kHz. On the onset of smectic A — Sc* transition, we observed co-existence of a target pattern, and a combination of an $S = +2$ disclination and a single strength disclination circulating with the electric field. The snap shot of this pattern is shown in figure 2.

At this instant even if we reduce the voltage pulse height to zero, thus removing the electric field, the high strength disclination remains stable in the film for several hours throughout the temperature range of Sc* phase. Figure 3 shows two micrographs of this stable high strength disclination in the absence of rotating electric field, at room temperature.

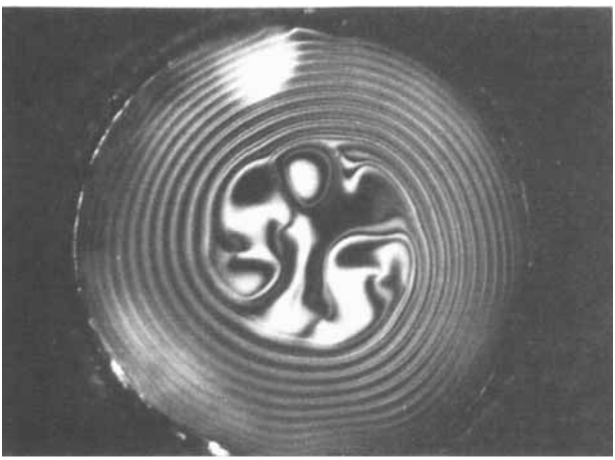

Figure 4: The micrograph of the film under the application of an electric field corresponding to the pulse height 107 V at rotational frequency of 750 Hz viewed with crossed polarisers at room temperature. The sample was illuminated with white light.

It is observed the values of the electric field strength and its rotational frequency govern the pattern formation in the Sc* phase. For example, figure 4 shows a different pattern formed when the film was cooled to the Sc* phase in the presence of an electric field produced by a voltage pulse of height 107 V and field rotation frequency of 750 Hz. The micrograph shows co-existence of a target pattern and five single strength disclinations circulating with the electric field. Besides these parameters the pattern formation also depends on whether the electric field was applied *before* or *after* the smectic A — Sc* phase transition.

CONCLUSION

For the first time, we have observed a +2 strength disclination in the free standing film of ferroelectric liquid crystal when cooled to its Sc* phase in the presence of a rotating electric field. The weak interactions between the molecules in the liquid crystal film coupled with the influence of the rotating electric field may be responsible for the creation of these interesting patterns. A detailed experimental and theoretical study of this system may lead to a better understanding of the physics of free standing liquid crystal films.

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