EXPLORING A NEW PHASE OF LIQUID CRYSTALS

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BACKGROUND & AIMS

Liquid crystals are well-known materials; you have probably used them multiple times today in the liquid crystal displays (LCD) around your home and conference hall. However, the unexplored 'ferroelectric nematic' (*Nf*) phase has yet unrealised potential in electronics due to its difficulty in identification. Identification has historically required advanced techniques, and here we improve upon a simple visual verification method developed by Rudquist, 2021. We explore the *Nf* phase under varying conditions, revealing an unexpected transition to a lower-order phase under strong fields at sub-transition temperatures.

THEORY

The *N* phase has apolar directors which do not align with the rubbing direction (Fig.1), while the *Nf* phase has polar directors that do align (Fig.2). This results in a twisted structure in anti-parallel linear microscopy cells (Fig.2b). These structures help understand the defect lines in parallel planar, circularly aligned cells (PPCA) (Rudquist, 2021). In the *Nf* phase, the polar director only aligns with the rubbing direction once (6 o'clock), resulting in a single defect (Fig.3) (Rudquist, 2021).

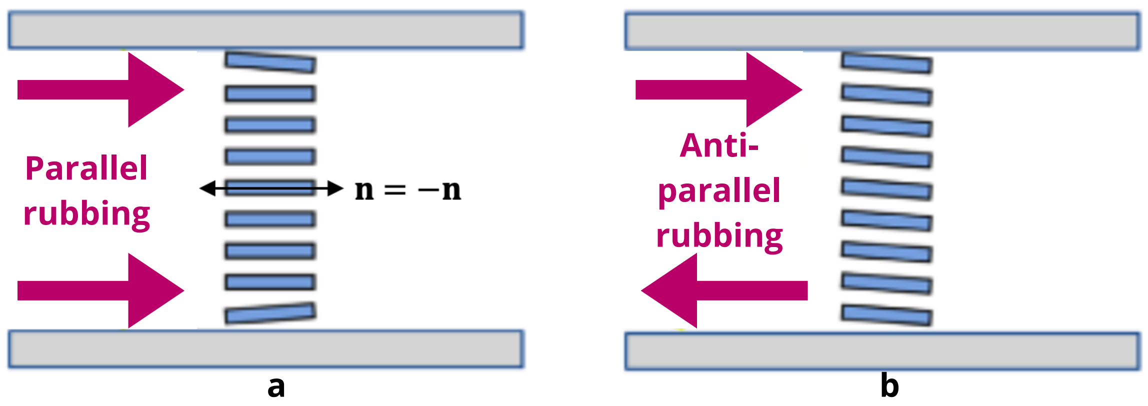
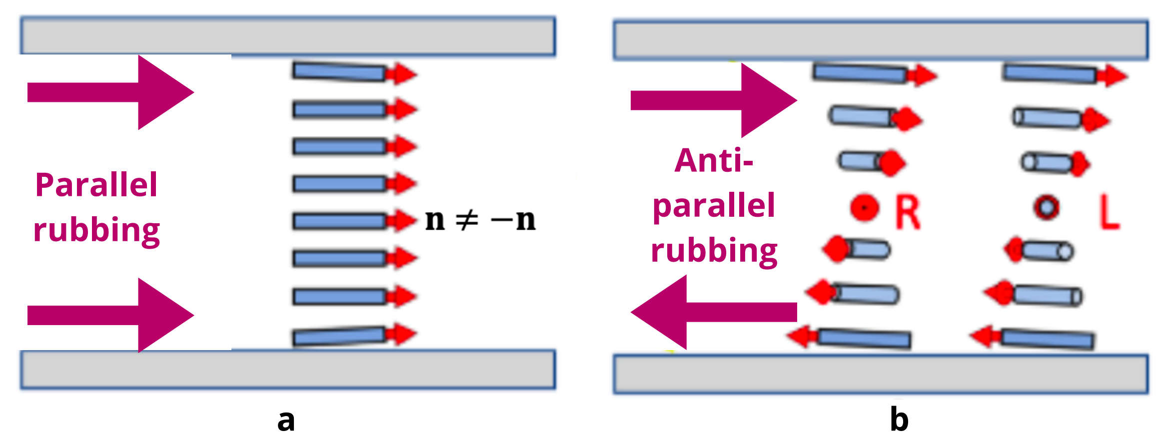


Figure 1. Diagram showing effects of sign invariant directors (n) on molecular alignment. Image adapted from (Rudquist, 2021).



Ferroelectric nematics display twist when filling colinear cells. Image adapted from (Rudquist, 2021).

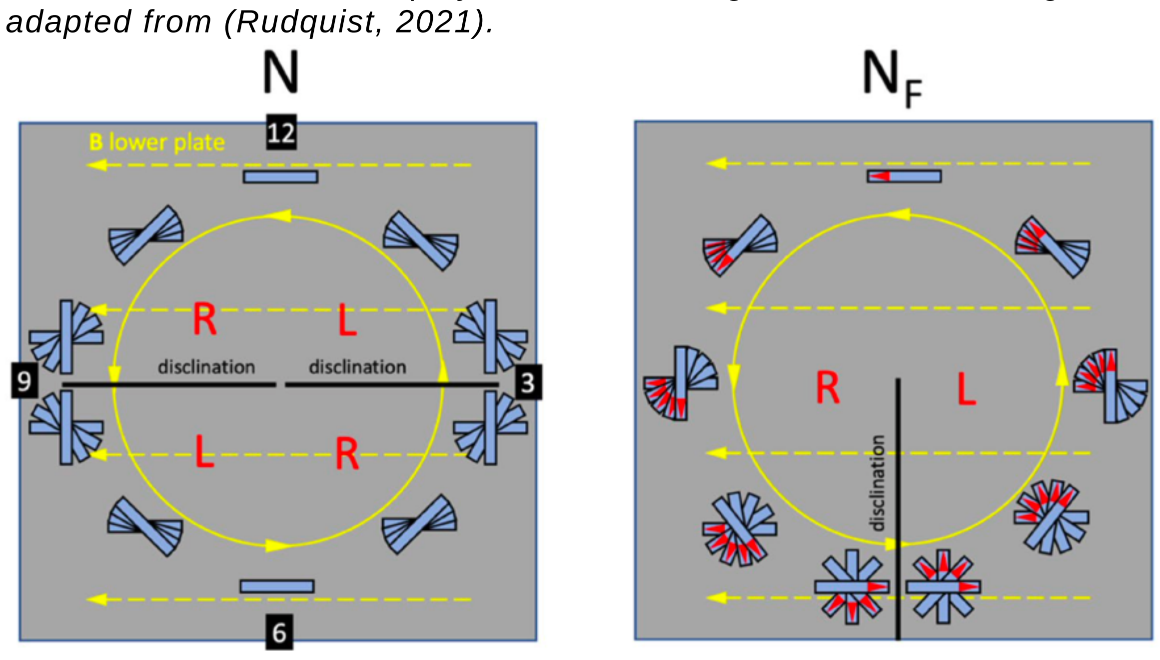


Figure 3. Characteristic defect lines corresponding with rubbing directions of PPCA substrates and accompanying director orientations (Rudquist.P 2021).

IDENTIFICATION

PPCA cells filled with M5 material were placed on a heatstage. The M5 material had a measured *Nf-N* phase transition at 43.5±0.1ºC, see the characteristic defect lines in Fig.4. The defect splits into two during the intermediate phase (*Nx*) at around 45ºC and then into nematic at ~55ºC (Fig.4b).

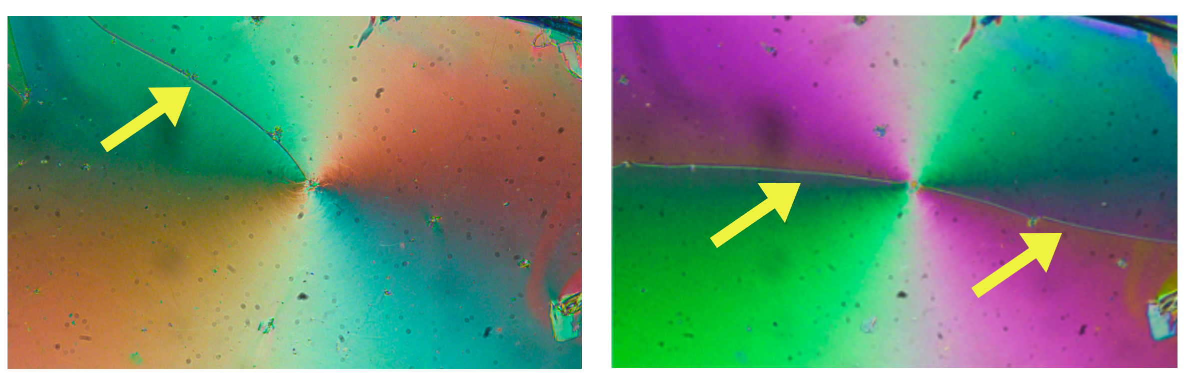


Figure 4. Timelapse of M5 heating in a PPCA cell from 40 ± 0.1°C to 65 ± 0.1°C at 1°C/min. Note the clear change from ferroelectric nematic (single defect) to nematic (double defect).

EXPOSURE TO ELECTRIC FIELDS

Samples were exposed to electric fields of varying strength to study effects on defect lines. The results hint at the inducement of apolar ordering at sub-transition when an electric field is applied, which was unexpected.

Figure 5. An induced electric field causing the characteristic Nf defect line to split at the sub-transition temperature of 43 ± 0.1°C.

Figure 5a. Single Nf defect intact at t = 0 ± 1s.

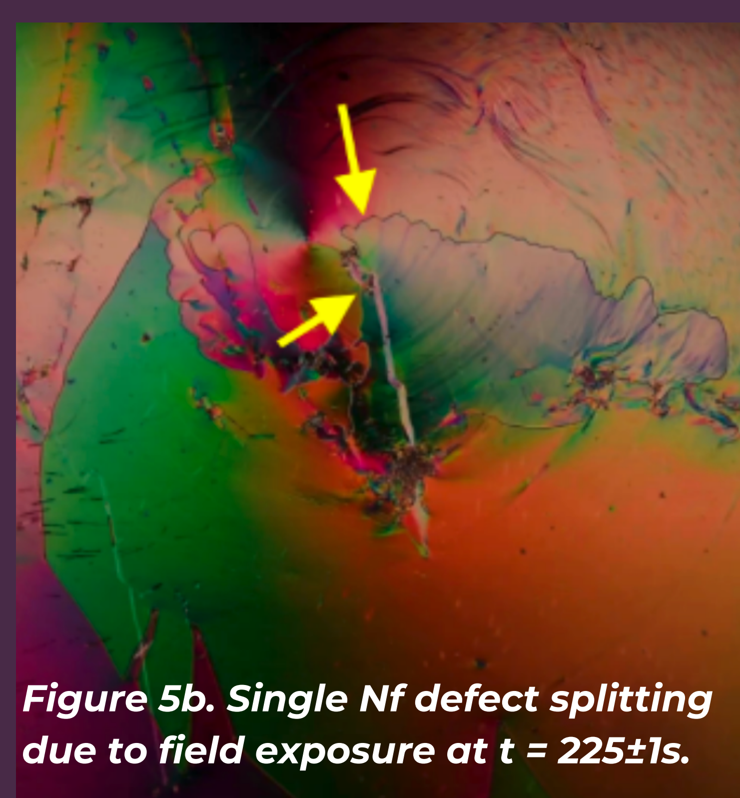


Figure 5b. Single Nf defect splitting due to field exposure at t = 225±1s.

REFERENCES

Rudquist, P. (2021) 'Revealing the polar nature of a ferroelectric nematic by means of circular alignment', Scientific Reports, 11(1), pp. 1–5. doi:10.1038/s41598-021-04028-7.

See the transition!