Simultaneous Measurements of Molecular Forces and Electro-Optical Properties of a Confined 5CB Liquid Crystal Film using a Surface Forces Apparatus (SFA)

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Estimate of number of 5CB molecules contributing to the refractive index change

By comparing the real value of the complex electric permittivity between the stationary case and abrupt voltage polarization change, we can estimate the number density N of 5CB molecules from the following equation:[1]

$$N = 3\varepsilon_0 k_B T \frac{\Delta\varepsilon_{zz}(\theta)}{\mu^2}, \qquad \text{(S1)}$$

where k_B is the Boltzmann constant, T (=296 K) is the temperature and μ is the electric dipole moment of the 5CB molecules (= 6.50 Debye). For the average value of $\Delta\varepsilon_{zz}$ of 1.5, Equation 1 gives $N = 3.5\times10^{20}$ molecules/ml. This means that 3.5×10^{19} molecules out of a 100 μl droplet of 5CB contribute to the refractive index change. This is 10% of the total number of 5CB molecules in the droplet (100 μl of 5CB with a molecular weight 249.45 g/mol and a density 1.008 g/ml give 2.4×10^{20} molecules).

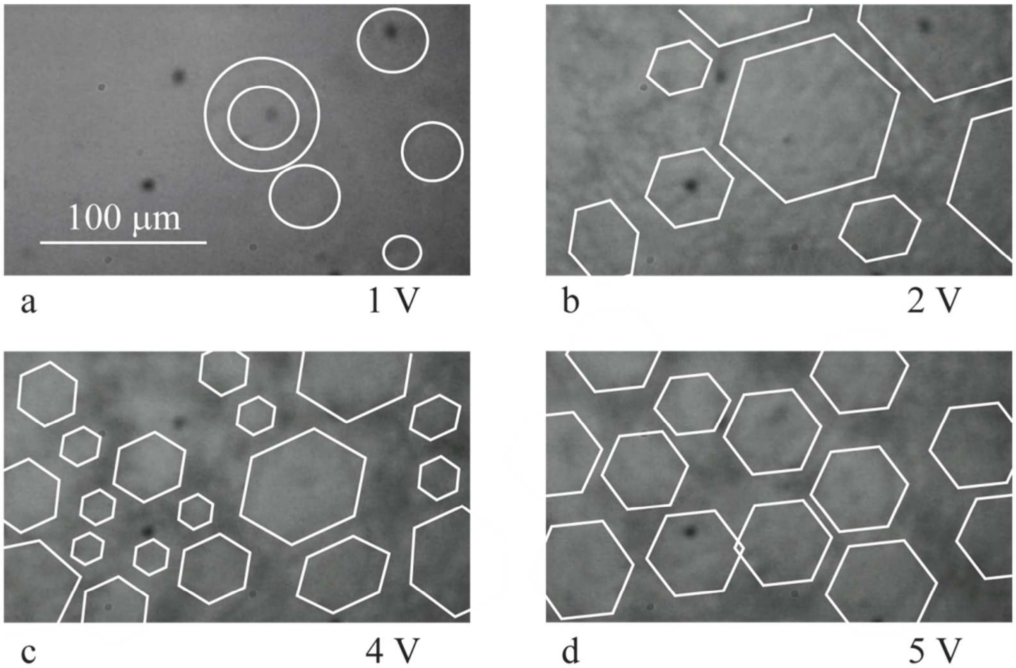

Figure S1. Same images as Figure 9, but with added lines (circular and hexagonal) that indicates the domain boundaries. Qualitative description of the development of the nucleation sites and boundary propagation of liquid crystals in electric fields of various strength. At low electric field (a-b) the boundary nucleates and propagates in expanding circular rings. (a) The boundaries are indicated as white circles. (b-d) With applied voltage higher than 1 V, all the area of liquid crystal is covered by fluctuating and propagating boundaries. The white circles and hexagons indicate domains of fluctuating boundaries, which is apparently separated from the rest of the liquid crystal. From 1.5 – 3 V the domains are large, thus the boundaries can propagate over long distance. In this region the shape of the domains turns from circular to hexagon due to close packing. From 3 – 5 V the domains get more separated (or defined) and break up to smaller units. At 5 V some of the domains merge and they form a more regular lattice of clearly separated hexagon domains.

Captions for video

Video SV1: FECO fringes of 5CB under an electric field induced by a square wave voltage of 2.0 V and frequency 0.05 Hz. The video starts before any voltage is applied, i.e., V = 0. After a few seconds the voltage is applied. Polarity reversal is observed when the fringes move abruptly to shorter or longer wavelengths reflecting the refractive index changes. The extraordinary fringes show a wavy motion along the lateral dimension indicating undulating domains. These undulating domains can also be observed through an optical microscope (top view, see Figure 1 and Video SV2). The asymmetry of the wavelength shift can be observed by two effects: First, the positions of the extraordinary fringes depend on the polarity of the applied voltage; second, the formation of the undulating domains occurs more rapidly in one direction compared to the other direction of the electric field.

Video SV2: Optical microscope top view of 5CB under an electric field induced by a square wave voltage of 2.0 V and frequency 0.05 Hz. The position of closest approach is in the center of the optical microscope video. The video starts before any voltage is applied, i.e., V = 0. After one second a voltage is applied and the domains start to fluctuate. In the absence of an applied voltage the domains do not fluctuate. Undulating domains are observed. The behavior of the domains is noticeably different on reversing the voltage, which reflects some asymmetry in the confined liquid crystal.

References

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