Photoinduced Displacement of Ferroelectric Nematic Liquid Crystal Droplets on the Surface of Lithium Niobate

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Introduction

The recent discovery of nematic liquid crystal molecules showing a ferroelectric order has marked a breakthrough in liquid crystal science [1,2]. In nematic liquid crystals the rodlike molecules align parallel to each other. However, the conventional nematic phase is not polar, as in average half of the molecules have their dipoles pointing in each of the two opposite directions associated to the director axis. On the contrary, ferroelectric nematic liquid crystals (FNLC) are polar fluids with alignment of their dipoles. In this work, we studied interaction of FNLCs with photovoltaic and/or pyroelectric fields generated on the surface of iron-doped lithium niobate crystals ($LiNbO_3$:Fe or LN) without requiring electrodes. When sessile droplets of a FNLC are placed onto the surface of an illuminated or heated/cooled x-cut $LiNbO_3$:Fe crystal, intriguing dynamic processes occur, such as strong flow of liquid crystalline material parallel to the direction of the photo-induced electric field.

Experimental results

An example of the observed dynamic processes, by using the DIO liquid crystal [1,3], is reported in Figure 1. In this experiment, the surface of the photorefractive LN crystal is pre-illuminated with a 532-nm laser beam focused in only one direction with a cylindrical lens to induced a space charge field perpendicular to the c-axis. Afterwards, DIO droplets are deposited on this surface. The LN crystal with DIO droplets is then placed under a polarizing optical microscope and is heated up until melting and then it is cooled down to a nematic phase. The different images of Figure 1 represent the evolution of FNLC droplets during cooling from 110°C to about 80°C with a temperature ramp of -5°C/min. The stripe-shaped region corresponding to a pseudo-permanent photo-induced refractive index change is highlighted in green. At first, the droplets change their shape from spherical (Figure 1(a)) to extended ellipsoidal (Figure 1(b)). Then, they start to rapidly move preferentially parallel to the direction of the crystal's plus and minus c-axis Figure 1(b and c). During this motion, several droplets merge into running streams extending towards the edges of the crystal. When the temperature is stabilized, the flow becomes weaker and the channels narrower (Figure 1(d)). Finally, practically all liquid-crystalline material is transferred from the top surface to the side or to the bottom surface of LN. This can be noticed in Figure 1(c) as a change of image from dark to bright.

This change in the transmitted light intensity is caused by the FNLC travelling under the crystal, which disappears out of frame of the camera in Figure 1(d). The liquid jets are mostly oriented along the crystal *c*-axis, parallel to the evanescent static electric field generated on its surface by pyroelectric and/or photovoltaic effects.

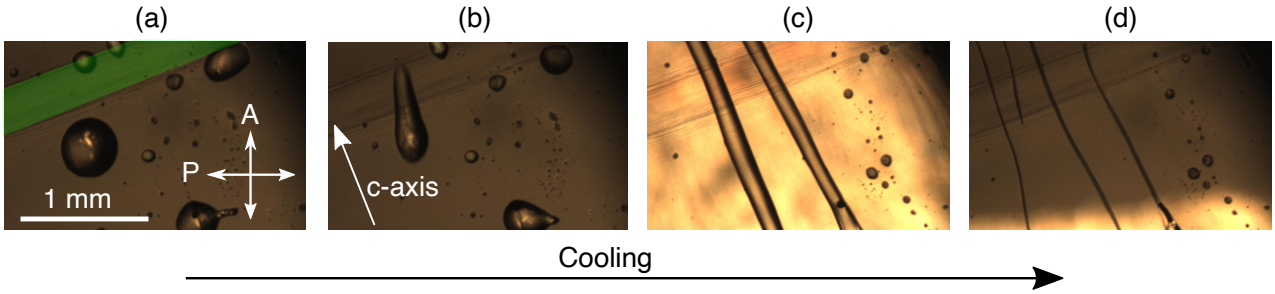

Figure 1: Example of strong displacement of DIO, a ferroelectric nematic liquid crystal, initiated by photo-induced electric field on the surface of $LiNbO_3$:Fe crystal while cooling down the crystal. Sessile droplets around 110°C (a), the droplets start to elongate (b) and abruptly transform into strong running streams (c), which become weaker when the temperature starts to stabilize around 80°C (d). The oblique region pre-illuminated by a 532-nm laser (perpendicular to the crystal's c-axis) presenting a photo-induced refractive index change is on the top left and can be seen in all images (highlighted in green in Fig.1a).

Conclusions

The observed phenomena depend on the optical field intensity, polarization, and spatial profile, and on the temperature ramp (inducing pyroelectricity). They are observed in the ferroelectric nematic phase, in the intermediate phase(s) and also in the standard nematic phase. Some dynamic processes also take place in the isotropic phase. We found that the above-described intriguing effects are reproducible also with other ferroelectric nematic liquid crystals. The strong and fast displacement of the material is initiated by the interaction of electrically charged/polarized fluid with charged surface of the photovoltaic LN crystal when electrostatic repulsion exceeds the surface tension of the fluid. Our results are in accordance with the results of very recent experiments conducted with FNLC RM257 on the LN surface initialed by pyroelectric field [4].

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References

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