Fabrication of Microwells to Host Liquid Crystals (LCs) for Studies Aimed at Understanding the Coupling of Surfactant Concentration Gradients with LC Ordering

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Primary CNF Tools Used: Heidelberg Mask Writer, ABM Contact Aligner, DISCO Dicing Saw

Abstract:

We have used the CNF to fabricate microwells to host liquid crystals (LCs) in studies aimed at understanding how surfactant concentration gradients impact the LC ordering. Specifically, microwells with various shapes were fabricated by patterning SU-8 on glass surfaces using photolithography. LCs were dispensed into the microwells to create LC domains with diverse shapes. We have discovered that the optical responses of the LC films depend strongly on the LC domain shape.

Summary of Research:

We used photolithography to fabricate microwells with a depth of ~ 20 μm and lateral dimensions ranging from 50 μm to 500 μm. SU-8 25 was used as the photoresist. The ABM contact aligner was employed for UV exposure of the films of SU-8 on glass wafers through a chrome mask written using the Heidelberg Mask Writer - DWL2000. The wafers were cut in the shape of microscope slides (75 mm × 25 mm) using the dicing saw. After treating the microwells with octadecyltrichlorosilane, we dispensed thin films of nematic LCs (5CB; Figure 1a) in them and attached them to the floor of a milli-fluidic channel (Figure 1c; detailed elsewhere [1]). A gradient in surfactant concentration (sodium dodecyl sulfate (SDS; Figure 1b)) was generated within the milli-fluidic channel by pumping two aqueous solutions containing different concentrations of SDS through the channel inlets under conditions of laminar flow (Figure 1c).

In response to a given external gradient in concentration of SDS, we observed the LC films to exhibit bright shape-dependent optical responses as presented in Figure 2. Although Figure 2 reveals a qualitatively similar progression of LC interference colors in the y-direction (direction of predicted SDS gradient) across each sample, independent of the shape of the LC film, the maximum optical retardance of the LC films and the width of the optically dark (extinct) bands were noted to differ significantly with a change in shape of the LC films.

We made systematic changes to the shapes of the LC films (lateral to the external gradient), ranging from the initial rectangular shapes to triangular shapes. We found that a select set of shapes generated a strong optical response (higher optical retardance) as presented in Figure 3. An inverted triangular shape (Figure 3 k-n) appears to be the LC domain shape that generates the strongest optical response.

In addition, we used rectangular LC films (prepared in rectangular microwells) to investigate how the non-equilibrium ordering of LCs driven by external gradients in surfactant concentration leads to the formation of localized assemblies of microparticles (Figure 4). Specifically, silica microparticles (diameter 3 μm), initially present in the bulk 5CB, were driven to the aqueous-LC interface and formed localized chains at the middle of the interface when placed in a milli-fluidic channel containing a gradient in SDS concentration.

References:

[1] Roh, S.; Tsuei, M.; Abbott, N. L. Using Liquid Crystals for *in situ* Optical Mapping of Interfacial Mobility and Surfactant Concentrations at Flowing Aqueous-Oil Interfaces. Langmuir 2021, 37 (19), 5810–5822. https://doi.org/10.1021/acs.langmuir.1c00133.

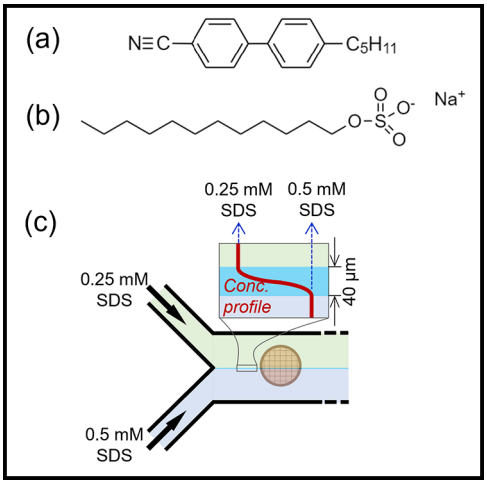


Figure 1: Molecular structure of (a) 4-Cyano-4'-pentylbiphenyl (5CB) and (b) Sodium dodecyl sulfate (SDS). (c) Aqueous solutions of SDS at 0.25 mM and 0.5 mM concentrations (color-coded as green and blue, respectively) are passed through two inlets of the milli-fluidic channel at a flow rate of 2 mL/min each. The concentration profile of SDS near the middle of the channel width is illustrated in the inset.

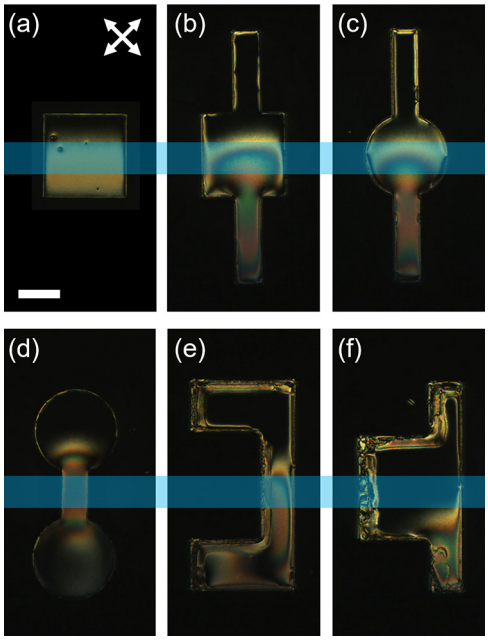
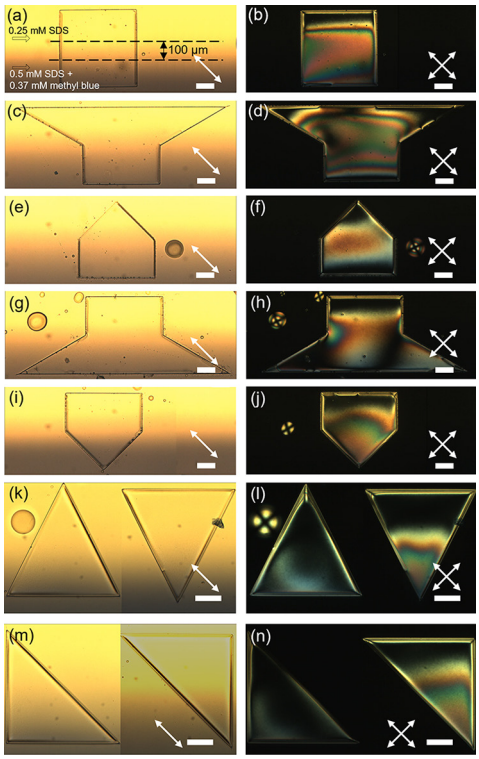


Figure 2: Optical response of 5CB confined in microwells of different shapes to a gradient in SDS concentration generated by pumping solutions of 0.5 mM and 0.25 mM SDS in 300 mM NaCl at a flow rate of 0.5 mL/min each. The blue bands passing through the middle of the films represent the position of the external gradient. Scale bar is 100 µm.



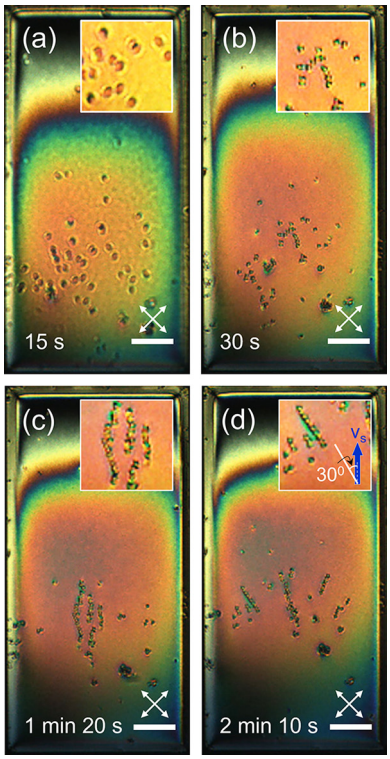


Figure 3, left: 0.25 mM SDS solution is pumped through one inlet and a solution containing 0.5 mM SDS and 0.37 mM methyl blue is pumped through the other inlet of the channel at a flow rate of 0.5 mL/min each. (a, c, e, g, i, k, m) Bright-field images of LC confined in microwells of different shapes. Black dotted lines in (a) represent the extent of the imposed gradients in the bulk aqueous solution. (b, d, f, h, j, l, n) Optical response of LC between cross polars. Scale bars are 100 µm. Figure 4, right: A film of 5CB with dispersed silica particles is placed inside a milli-fluidic channel containing a gradient in SDS concentration generated by pumping solutions of 0.5 mM and 0.25 mM SDS in 300 mM NaCl at a flow rate of 0.5 mL/min each. Insets show magnified views of the organizations of particles in the time series images. Scale bars are 50 µm.