Supporting Information

Electrothermally Driven Structural Colour Based on Liquid Crystal Elastomers

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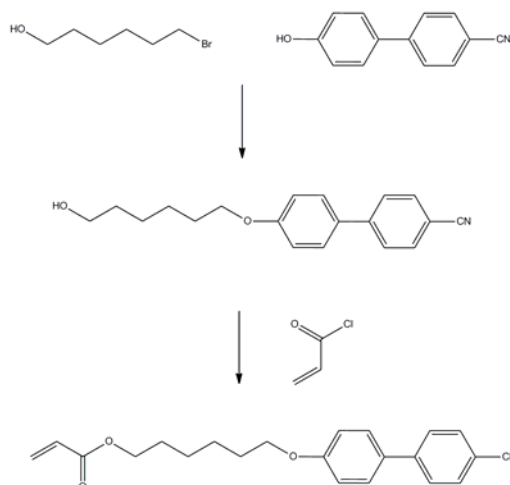
Synthesis and characterization of the LC monomer (MP)

Image of LCEs based inverse opaline film

Evaluation of the soluble content (sol.-%)

Swelling behavior

Synthesis and characterization of the LC monomer (MP)

Scheme. S1 Synthesis the LC monomer (MP)

4'-(6-Hydroxyhexyloxy)-4-biphenylcarbonitrile. A mixture of 4'-hydroxy-4-biphenylcarbonitrile (2.00 g, 10.2 mmol) and KOH (0.57 g, 10.2 mmol) in ethanol (60 mL) was refluxed for 20 min. To this solution was added dropwise a solution of 6-bromohexane-1-ol (1.6 mL, 11.2 mmol) in ethanol (10 mL) at room temperature. After addition, the reaction mixture was refluxed for 24 h, and the solvent was evaporated. The residue was extracted with diethyl ether, and the ether layer was washed with aqueous saturated sodium carbonate solution and dried over anhydrous magnesium sulfate. The solvent was evaporated to produce a white solid. Recrystallization from methanol gave white needles. ^{1}H-NMR (300 MHz, CDCl$_3$) δ (ppm): 1.40-1.80 (m, 8H, CH$_2$), 3.60 (t, 2H, HOCH$_2$), 4.01 (t, 2H, PhOCH$_2$), 7.00 (d, 2H, Ar-H, *ortho* to OCH$_2$), 7.52 (d, 2H, Ar-H, *meta* to OCH$_2$), 7.64 (d, 2H, Ar-H, *ortho* to CN), and 7.67 (d, 2H, Ar-H, *meta* to CN).

6-(4'-Cyanobiphenyloxy)hexyl Acrylate (MP). A solution of acryloyl chloride (0.675 mL, 8.30 mmol) was added dropwise to an ice-cooled solution of 4'-(6-Hydroxyhexyloxy)-4-biphenylcarbonitrile (1.95 g, 5.57 mmol) and TEA (1.175 mL, 8.375 mmol) in THF (10 mL). After addition, the mixture was stirred for 12h at room temperature, and the solvent was evaporated. The residue was extracted with diethyl ether, and the ether layer was washed with water and dried over anhydrous magnesium sulfate. The solvent was evaporated under pressure to produce a white solid. Recrystallization from methanol gave white needles, mp 73-74℃. ^{1}H-NMR (300 MHz, CDCl$_3$) δ (ppm): 1.50 (m, 4H, CH$_2$), 1.73 (m, 2H, CH$_2$), 1.82 (m, 2H, CH$_2$), 4.01 (t, 2H, PhOCH$_2$), 4.18 (t, 2H, COOCH$_2$), 5.82 (dd, 1H, CH$_2$= CH- (cis)), 6.14 (dd, 1H, CH$_2$=CH-), 6.41 (dd, 1H, CH$_2$=CH-(trans)), 7.00 (d, 2H, Ar-H, *ortho* to OCH$_2$), 7.52 (d, 2H, Ar-H, *meta* to OCH$_2$), 7.64 (d, 2H, Ar-H, *ortho* to CN), and 7.67 (d, 2H, Ar-H, *meta* to CN). ^{13}C-NMR (75 MHz, CDCl$_3$) δ (ppm): 25.6 (1C, CH$_2$), 25.8 (1C, CH$_2$), 28.6 (1C, CH$_2$), 29.2 (1C, CH$_2$), 64.6 (1C, COO$\underline{C}$H$_2$), 68.0 (1C, CH$_2$OAr), 110.1 (1C, Ar-C, *ipso* to CN), 115.1 (2C, Ar-C, *ortho* to OCH$_2$), 119.2 (1C,-CN), 127.2 (2C, Ar-C, *meta* to CN), 128.4 (2C, Ar-C, *meta* to OCH$_2$), 128.7 (1C, CH$_2$=$\underline{C}$H-), 130.7 (1C, Ar-C, *para* to OCH$_2$), 131.3 (1C, $\underline{C}$H$_2$=CH-), 132.7 (2C, Ar-C, *ortho* to CN), 145.3 (1C, Ar-C, *para* to CN), 159.8 (1C, Ar-C, *ipso* to OCH$_2$), 166.4 (1C,CH$_2$CH$\underline{C}$OO-).

Image of LCEs based inverse opaline film

Figure S2. The image illustrating the physical aspect of the LCEs based inverse opaline film. The bars in the images stand for 5 mm.

Evaluation of the soluble content (sol.-%)[60]

The quantity of the soluble content, i.e. corresponding to the non-cross-linked parts, e.g. unreacted monomers, free oligomers, etc.., of the obtained gel was performed for 3 days in a soxhlet, using cyclohexane as solvent. The cleaned gel was then dried under vacuum for 3 days. The soluble content was calculated with the following equation:

$$\text{sol.-\%} = V_{initial} - V_{final},$$

where $V_{initial}$ is the initial weight of the dried elastomer and V_{final} is the weight of the dried elastomer after washing and removal of soluble species.

The $C_X = 10\%$ LCEs film's soluble content extracted with hexane is 4.13%

Swelling behavior[60]

Swelling experiment was performed in toluene. The degree of swelling was calculated with the following equation:

$$q = V_{swollen} / V_{dry},$$

in which q is the swelling factor, $V_{swollen}$ is the volume of the swollen gel and V_{dry} is the initial volume of the dry gel.

The swelling ratio in a given direction of the gel is expressed by the equation:

$$\alpha_i = l_{i\,swollen} / l_{i\,dry},$$

where α_i is the swelling ratio in the i direction, and l is the size in the swollen dry state. In the case of bulk elastomers, the direction parallel to the director ($l_{//}$) was defined as the rubbing direction of the film. Therefore, $\alpha_{//}$ is the swelling coefficient parallel to the director and $\alpha_{\perp}$ is the swelling coefficient perpendicular to the director. Thus, if we consider that the swelling in the two perpendicular directions is the same, the degree of swelling can be rewritten as:

$$q = \alpha_{//} \times \alpha_{\perp} \times \alpha_{\perp}$$

In order to determine the difference of swelling as a function of the direction, the swelling anisotropy (Δq) can be determined by:

$$\Delta q = \alpha_{\perp} \, / \, \alpha_{//}$$

The C_X = 10% LCEs film's swelling factor of q = 6.32 ($\pm$ 0.5), and swelling anisotropy is Δq = 1.8 ($\pm$ 0.2).