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Supplementary Information

# Chiral Nematic Liquid Crystal Droplets as a Basis for Sensor Systems

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## 1. Energy comparison for rotating a LC droplet or reorienting its director field

If we assume a 10 µm diameter droplet rotates at 2πs$^{-1}$:

The rotational kinetic energy of the droplet is given by;

$$U_r = \frac{1}{5} m r^2 \omega^2 \quad , \qquad (1)$$

Mass of droplet m;

$$m = \frac{4\pi}{3} \rho r^3 \quad , \qquad (2)$$

Hence;

$$U_r = \frac{4\pi}{15} \rho r^5 \omega^2 \quad , \qquad (3)$$

The strong $r^5$ dependence on droplet size is because the mass of the droplet increases with $r^3$ and the rotational energy increases with $r^2$.

**Table ST1.** Example values of rotational kinetic energy ($U_r$) for a droplet of 5CB (ρ = 1.01 kgm$^{-3}$) with droplet diameters of 10 and 20 µm.

| **4π/15** | **ρ (kgm$^{-3}$)** | **r (m)** | **ω (rads$^{-1}$)** | **$U_r$ (J)** |
|---|---|---|---|---|
| 0.838 | 1.01 x 10$^{3}$ | 1.00 x 10$^{-5}$ | 6.28 | 3.31 x 10$^{-21}$ |
| 0.838 | 1.01 x 10$^{3}$ | 2.00 x 10$^{-5}$ | 6.28 | 1.06 x 10$^{-19}$ |

For a droplet of *r* = 10 µm, 3.31 x 10$^{-21}$ J is needed to rotate the droplet once per second; whereas for a droplet of *r* = 20 µm, 1.06 x 10$^{-19}$ J is need to rotate the droplet once a second. This is double the order of magnitude.

**Reorienting the director field of a droplet**

Approximating the droplet to a cylinder of dimension 2*r*, we can then approximate this to a circular section with a cell gap of 2*r*. Estimating that the director switches the bulk of the droplet in ~ 2V and that the change in capacitance is ~ 50% of Δε (which is ≈ 20);

$$U_n = \frac{1}{2}\Delta C V^2 , \qquad (4)$$

$$\Delta C = \frac{\pi r^2}{2r}\varepsilon_0 \Delta\varepsilon = \frac{\pi \varepsilon_0}{2} r \Delta\varepsilon , (5)$$

$$U_n = \frac{\pi \varepsilon_0}{4} r \Delta\varepsilon V^2 , \qquad (6)$$

As the droplet increases in radius, so does the volume of fluid in which the elastic deformation is taking place. This will follow *r*$^3$. However, as *r* increases, the same elastic energy decreases and this will follow *r*$^2$.

**Table ST2.** Example values of director reorientation energy ($U_n$) for a droplet of 5CB with droplet diameters of 10 and 20 µm.

| $\pi\varepsilon_0/4$ | K (pN) | Δε | V (V) | r (m) | $U_n$ (J) |
|---|---|---|---|---|---|
| $6.91 \times 10^{-12}$ | 30 | 20 | 2.00 | $1.00 \times 10^{-5}$ | $5.53 \times 10^{-15}$ |
| $6.91 \times 10^{-12}$ | 30 | 20 | 2.00 | $2.00 \times 10^{-5}$ | $1.11 \times 10^{-14}$ |

Therefore, for a small droplet, it is easier to rotate the whole droplet than to reorient the director field.

*These values assume K ≈ 30 pN. A K ≈ 15 pN (closer to a real value for 5CB) is used below but the order of magnitude for $U_n$ remains unchanged.

### Cross-over droplet size

The point at which $U_n = U_r$ allows for a cross-over radius to be found;

$$r^4 = \frac{15\varepsilon_0 \Delta\varepsilon V^2}{16 \;\; \rho\omega^2} , \qquad (7)$$

**Table ST3.** Example values of rotational kinetic energy ($U_r$) and director reorientation energy ($U_n$) for a droplet of 5CB.

| 4π/15 | ρ (kgm$^{-3}$) | r (m) | ω (rads$^{-1}$) | $U_r$ (J) | $\pi\varepsilon_0/4$ | K (pN) | Δε | V (V) | $U_n$ (J) |
|---|---|---|---|---|---|---|---|---|---|
| 0.838 | $1.01 \times 10^3$ | $1.00 \times 10^{-5}$ | 6.28 | $3.31 \times 10^{-21}$ | $6.91 \times 10^{-12}$ | 15 | 10 | 2.00 | $2.76 \times 10^{-15}$ |
| 0.838 | $1.01 \times 10^3$ | $2.00 \times 10^{-5}$ | 6.28 | $1.06 \times 10^{-19}$ | $6.91 \times 10^{-12}$ | 15 | 10 | 2.00 | $5.53 \times 10^{-15}$ |
| 0.838 | $1.01 \times 10^3$ | $4.00 \times 10^{-5}$ | 6.28 | $3.39 \times 10^{-18}$ | $6.91 \times 10^{-12}$ | 15 | 10 | 2.00 | $1.11 \times 10^{-14}$ |
| 0.838 | 1.01 x | 8.00 x | 6.28 | 1.08 | 6.91 x | 15 | 10 | 2.00 | 2.21 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | $10^{3}$ | $10^{-5}$ | | x $10^{-16}$ | $10^{-12}$ | | | | x $10^{-14}$ |
| 0.838 | 1.01 x $10^{3}$ | 1.60 x $10^{-4}$ | 6.28 | 3.47 x $10^{-15}$ | 6.91 x $10^{-12}$ | 15 | 10 | 2.00 | 4.42 x $10^{-14}$ |
| 0.838 | 1.01 x $10^{3}$ | 3.20 x $10^{-4}$ | 6.28 | 1.11 x $10^{-13}$ | 6.91 x $10^{-12}$ | 15 | 10 | 2.00 | 8.85 x $10^{-14}$ |
| 0.838 | 1.01 x $10^{3}$ | 6.40 x $10^{-4}$ | 6.28 | 3.55 x $10^{-12}$ | 6.91 x $10^{-12}$ | 15 | 10 | 2.00 | 1.77 x $10^{-13}$ |
| 0.838 | 1.01 x $10^{3}$ | 1.28 x $10^{-3}$ | 6.28 | 1.14 x $10^{-10}$ | 6.91 x $10^{-12}$ | 15 | 10 | 2.00 | 3.54 x $10^{-13}$ |

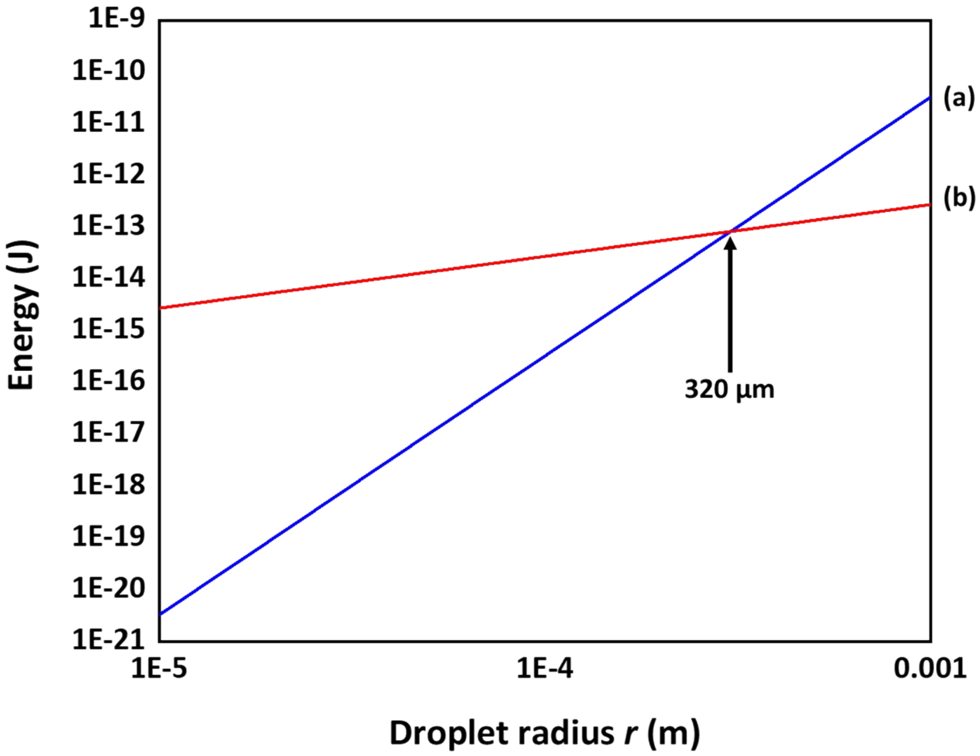

**Figure S1.** Plot of the cross-over point where it becomes more energetically favourable to reorient the director rather than the rotate the droplet. (a) Kinetic energy for rotation of a droplets of various sizes ($U_r$), (b) director reorientation energy for droplets of varying size ($U_n$).

It is clear that for droplets in the range 10 – 100 µm it will always be less energetically costly to rotate the whole droplet than to reorient the director field. Whilst these calculations have been done with an assumption that K ≈ 15 pN it is highly likely a similar trend would emerge for less elastically costly materials.

## 2. Tables

**Table ST4.** The compositions of samples and their calculated pitch values.

| LC | S1011 concentration (wt%) | R5011 concentration (wt%) | Calculated pitch (nm) |
|---|---|---|---|
| 5CB | 7.3 | | 343 |
| 6CB | 7.3 | | 343 |
| 7CB | 7.4 | | 337 |
| 5CB | 0.53 | | 4717 |
| E7 | 8.2 | | 305 |
| MLC7023 | | 1.9 | 439 |
| MLC7023 | 0.53 | | 4717 |

## 3. Figures

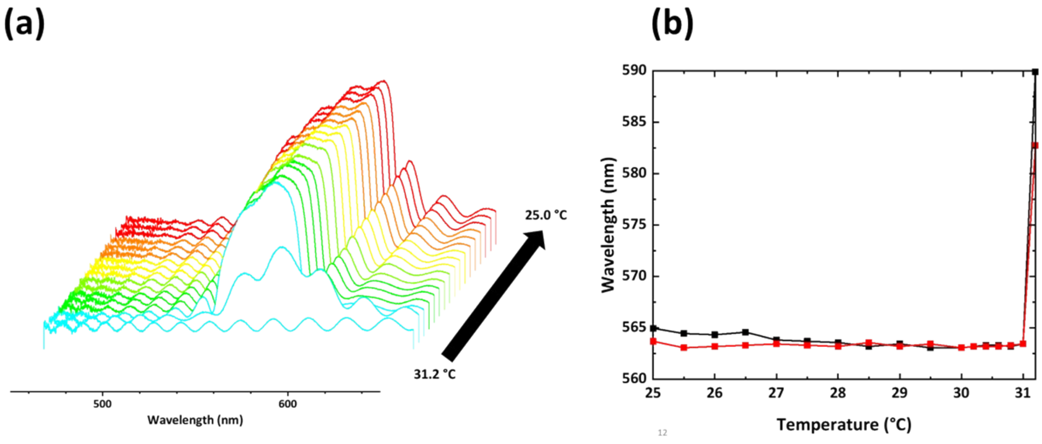

**Figure S2.** Temperature dependent reflection spectra of 5CB doped with 7.3 wt% S1011. (a) Reflection spectra obtained as the sample is cooled from the isotropic to 25 °C. The peak wavelength is 544 nm, and the full width at half maximum is 55 nm. (b) The peak wavelength plotted against temperature showing no temperature-dependence.

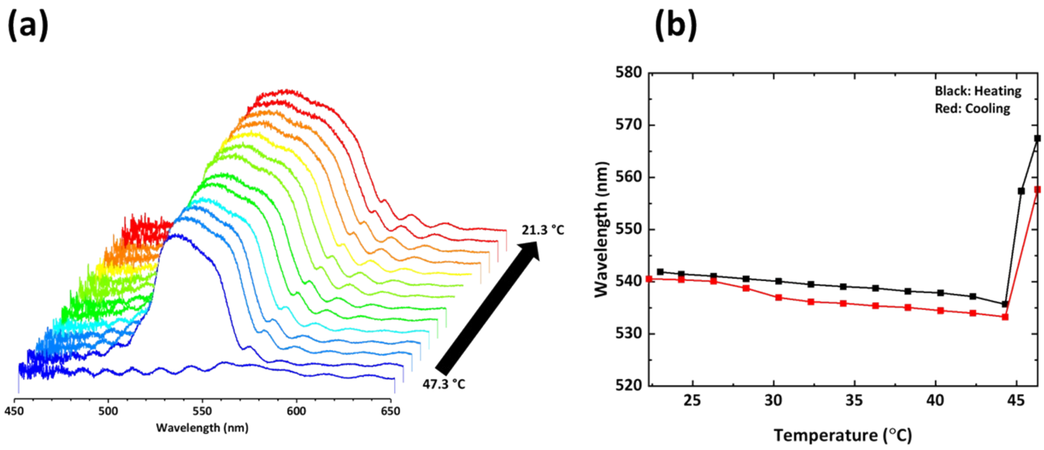

**Figure S3.** Temperature dependent reflection spectra of E7 doped with 8.2 wt% S1011. (a) Reflection spectra obtained as the sample is cooled from the isotropic to 21 °C. (b) The peak wavelength plotted against temperature showing no temperature-dependence.

## 4. Videos

**Video SV1.** A video of a DOPC:DOPG coated droplet of MLC7023 doped with 0.53 wt% S1011 and switched with 0.1 wt% SDS.

**Video SV2.** A video of a DOPC:DOPG coated droplet of MLC7023 doped with 1.9 wt% R5011 and switched with 0.1 wt% SDS.

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