TALKS LIST

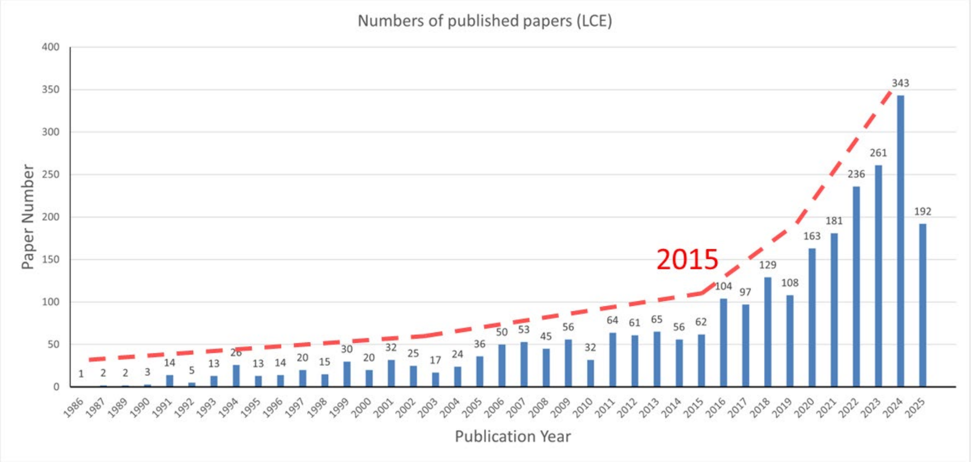
Liquid crystal elastomers as soft actuators

Min-Hui Li*

Chimie ParisTech, Université PSL, CNRS, Institut de Recherche de Chimie Paris, 11 rue Pierre et Marie Curie, Paris, France

* *The corresponding author e-mail: min-hui.li@chimieparistech.psl.eu*

At a time when the expansion of artificial systems through our society is rapidly blooming, the research on soft actuators that exhibit outstanding reversible shape-memory properties when exposed to external stimulations becomes more and more appealing. In 1975, Pierre-Gilles de Gennes[1] already predicted that liquid crystal elastomers (LCEs) could present unusual properties that classical rubbers had not, because LCEs combine the anisotropic properties of liquid crystals (LC) and elastic properties of elastomers. Since then, especially in the last decade, LCEs are extensively studied and increasingly considered as one of the competitive smart soft materials due to their outstanding thermotropic properties including large and reversible skeletal-muscle-like strain, tunable processability, and high programmability.[2-8] In this talk I will try to present, from a chemical point of view, the history of LCEs and the state of the art of LCEs as soft actuators.



References

[1] P. -G. de Gennes, *CR Acad. Sci. Paris, Ser. B* **1975**, *281*, 101.

[2] J. Küpfer, H. Finkelmann, *Makromol. Chem. Rapid Commun.* **1991**, *12*, 717.

[3] P.-G. de Gennes, M. Hébert, R. Kant, *Macromol. Symp.* **1997**, *113*, 39.

[4] T. Warner, E. M. Terentjev, *Liquid Crystal Elastomers*. Oxford Univeristy Press: **2003**.

[5] M.-H. Li, P. Keller, *Phil. Trans. R. Soc. A,* **2006**, *364*, 2763.

[6] C. Ohm, M. Brehmer, R. Zentel, *Adv. Mater.* **2010**, *22*, 3366.

[7] T. J. White, D. J. Broer, *Nat. Mater.* **2015**, *14*, 1087.

[8] K. M. Herbert, H. E. Fowler, J. M. McCracken, K. R. Schlafmann, J. A. Koch, T. J. White, *Nat. Rev. Mater.* **2021**, *7*, 23.

Electroactive Liquid Crystal Elastomers with Low Phase Transition Temperature

Yakui Deng[1], Gaoyu Liu[1], Annie Brûlet[2], Daniel Dudzinski[2], Frédéric Vidal[3], Giao T. M. Nguyen[3], Cédric Vancaeyzeele[3], Cédric Plesse[3], Min-Hui Li[1*]

[1] Chimie ParisTech, Université Paris Sciences & Lettres, CNRS, Institut de Recherche de Chimie Paris, 11 rue Pierre et Marie Curie, 75005 Paris, France, [2] Laboratoire Léon Brillouin, Université Paris-Saclay, UMR12 CEA-CNRS, CEA Saclay, 3 rue Joliot Curie, 91191 Gif sur Yvette cedex, France, [3] CY Cergy Paris Université, Laboratoire de Physicochimie des Polymères et des Interfaces (LPPI), 5 mail Gay Lussac, 95031 Cergy-Pontoise Cedex, France

** The corresponding author e-mail: min-hui.li@chimieparistech.psl.eu*

Over the past decades, liquid crystal elastomers (LCEs) as stimuli-responsive smart soft materials have attracted more and more attention. Most LCE-based materials use heat or light as external stimulus, where the LC order and the anisotropy of liquid crystal polymer (LCP) chain conformation are changed by temperature variation or light illumination. However, electrical energy is the most convenient and the most in demand stimulus in real applications. Nowadays, research on electroactive LCEs (eLCEs) has become a compelling direction.

Recently, our group have elaborated ionic eLCEs by incorporating ion-conducting materials inside LCEs [1,2]. We have reported the first bifunctional ionic eLCE device (i-EAD-LCE), where an ion-conducting LCE is sandwiched by two electrically conducting polymer electrodes composed of formulated PEDOT:PSS [1]. The i-EAD-LCE can perform both bending deformation and linear contraction/elongation by controlling electrical stimulation of low voltages (±2 V at 0.1 Hz or ±6 V at 10 Hz). Further, to enhance the mechanical properties of eLCE, the central ion-conducting LCE of the device has been replaced by two interpenetrating polymer networks (IPN) composed of a LCE and an ionogel to prepare a new trilayer device i-EAD-IPN-LCE [2]. This i-EAD-IPN-LCE can function not only as electroactive bending and linear actuators by controlling electrical stimulation of low voltages (±5 V at 0.1 Hz or ±10 V at 10 Hz), but also as a mechanical bending sensor to output electrical signals. Nevertheless, in both i-EAD-LCE and i-EAD-IPN-LCE, the N-I phase transition temperatures (T_{NI}) are above 80 °C, which limits its practical application in many fields. The objective of this work is then to reduce the value of T_{NI}. We have achieved to prepare a new central ion-conducting IPN layer with interpenetrating ionogel and LCE with T_{NI} as low as 43 °C. LC monomers with two-benzyl-rings and three-benzyl-rings were mixed to adjust the π–π interaction between mesogen cores to reduce T_{NI} of LCE. The trilayer ionic electroactive device elaborated with this new IPN-LCE can function as bending or linear actuator by controlling electrical stimulation of very low voltages (±2 V at 0.1 Hz or ±3 V at 10 Hz). This system is promising for future real applications.

References

[1] G. Liu, Y. Deng, B. Ni, G. T. M. Nguyen, C. Vancaeyzeele, A. Brulet, F. Vidal, C. Plesse, M.-H. Li, *Small*, **20**, 2307565 (2024)

[2] Y. Deng, G. Liu, A. Brûlet, G. T. M. Nguyen, D. Dudzinski, F. Vidal, C. Plesse, C.Vancaeyzeele, M.-H. Li, *Adv. Funct. Mater.*, **34**, 2403892 (2024)

Acknowledgments

This work was supported by the French National Research Agency (ANR-22-CE06-0023, AS-LCE).

Reprogrammable All-Solid-State Ionic Liquid Crystal Elastomers as Electroactive Actuators

Wei Ji[1], Yakui Deng[1], Cédric Plesse[2], Min-Hui Li[1*]
[1] Chimie ParisTech, Université Paris Sciences & Lettres, CNRS, Institut de Recherche de Chimie Paris, UMR8247, 11 rue Pierre et Marie Curie, 75005 Paris, France
[2] CY Cergy Paris Université, Laboratoire de physicochimie des polymères et des interfaces (LPPI), 5 mail Gay Lussac, Cergy-Pontoise, Cedex 95031, France
[*] The corresponding author e-mail: min-hui.li@chimieparistech.psl.eu

Liquid crystal elastomers (LCEs) are a family of stimuli-responsive smart soft materials that can find applications in the fields of artificial muscles, soft robotics and sensors.As actuators, electroactive liquid crystal elastomers (eLCEs) have attracted more and more attention from material researchers and engineers, because electrical energy is the most convenient and the most in-demand stimulus in real applications. We are interested in the ionic eLCEs that can convert either electrical stimulation into reversible large contraction or bending deformations under low driving voltage. In our previous work [1], an ionic eLCE actuator with both linear and bending actuations under low voltage of different frequencies has been developed, but the ionic liquids associated with the ionogel in that system present a leakage issue. To inherently solve the ionic liquid leakage issue, the polymeric ionic liquid (PIL) networks can be designed [2], in which either ionic liquid-like anions or cations are fixed to the elastomer backbone. In addition, to meet the demands of complex work and environmental protection, reprogrammability has been a priority in the design of the LCE and the introduction of hydrogen bonds is one of effective methods to endow reprogrammability [3]. Here, we use a bi-functional chain extender to introduce the PILs with ease, to solve the liquid leakage problem while enhancing the mechanical properties of the eLCE. Further, by the insertion of a tetrahydrogen bond monomer, a supramolecular network will be formed in the eLCE, making it reprogrammable. This all-solid-state eLCE enables stable and reversible actuation useful in soft robots.

References

[1] G. Liu, Y. Deng, B. Ni, G. T. M. Nguyen, C. Vancaeyzeele, A. Brûlet, F. Vidal, C. Plesse, and M. Li, *Small*, **20**, 2307565 (2024)
[2] F. B. Ribeiro, B. Ni, G. T. M. Nguyen, E. Cattan, A. S. Shaplov., F. Vidal, and C. Plesse, *Adv. Mater. Interfaces*, **10**, 2202381 (2023)
[3] Z. Wang, M. Si, J. Han, Y. Shen, G. Yin, K. Yin, P. Xiao, and T. Chen, *Angew. Chem. Int. Ed*, e202416095 (2024)

Acknowledgments

This work was supported by the French National Research Agency (ANR-22-CE06-0023, AS-LCE).

Design and investigation of mesomorphic π-conjugated materials

Benoît Heinrich,[1]* Stéphane Méry,[1] Fabrice Mathevet,[2] Piotr Ślęczkowski,[3]
[1]*IPCMS, CNRS-Université de Strasbourg, 23 rue du Loess, 67034 Strasbourg cedex*
[2]*IPCM, Sorbonne Université, 4 Place Jussieu, 75252 Paris cedex 5*
[3]*International Centre for Research on Innovative Biobased Materials (ICRI-BioM), Lodz University of Technology, 116 Zeromskiego St., 90-924 Lodz, Poland*
*benoit.heinrich@ipcms.unistra.fr

Molecules dedicated to molecular electronics or other functional material device applications involve in general one or several π-conjugated units conferring the functionality and saturated segments impacting the physical and structural properties, most often aliphatic chains. The primary role of these segments is to render the material more soluble, condition for the easy and low-cost fabrication of the thin films implemented in the optoelectronic devices.[1] Corollary, the introduction of chains causes the nanostructuration of the material, with formation of stratified liquid, liquid crystal or mesomorphic solid, depending on the molecular architecture.[2]

Mesomorphic properties and nanostructure can be tailored through the type, shape and position of saturated segments. In this line, our synthetical efforts focus on molecular architectures implementing ramified alkyl chains and siloxane chains.[3] The reason of this choice is that these chains strongly inhibit the crystallization of the material and promote the fluid or soft **room-temperature** nanostructured states. Among these, a particular interest arouse from soft-crystalline states, defined as long-distance correlated tridimensional structures involving molten zones in the lattice.[4]

These states are scarcely reported in literature, although they are more frequent and cataloged as classical crystal phases.[5] The main reason for this should be the complexity of their signature in X-ray scattering relegating them at the boundary of mesomorphism. However, the combination of scattering patterns obtained in laboratory conditions on the bulk material and at synchrotron on thin films allows the elucidation of the structure and the understanding of the molecular self-assembly. Beyond the scientific interest of the exploration of new phases, these architectures are promising for the elaboration of performing functional materials, for both the control of the interactions between π-conjugated units and the efficiency of thin film fabrication procedures.

References

[1] Ibraikulov et al., *Sol. RRL* **2019**, *1900273*.
[2] Del Giudice et al., *Eur. J. Org. Chem.* **2021**, 2091-2098.
[3] Kamatham et al., *Adv. Funct. Mater.* **2021**, *31*, 2007734.
[4] Shaya et al., *Molecules* **2023**, *28*, 2038.
[5] Ślęczkowski et al., *J. Phys Chem.*, **2024**, 128, 21826-21835.

SHG-active chiral bipyrimidine-based liquid crystalline thin films for 3D data storage

Nicolas, Prescillia[1]; Bellec, Nathalie[1]; Jeannin, Olivier[1]; Borat, Umut[2], Bilgin-Eran, Belkiz[2]; Akdas-Kiliç, Huriye[2]; Abdallah, Stephania[3], Malval, Jean-Pierre[3]; Dok, Ahmet[4]; de Coene, Yovan[4]; Verbiest, Thierry[4]; van Cleuvenbergen, Stijn[4]; Clays, Koen[4]; Camerel, Franck*[1]

[1] Institut des Sciences Chimiques de Rennes CNRS-UMR 6226 Université de Rennes, Rennes, France; [2] Department of Chemistry, Yildiz Technical University, Istanbul, Turkey; [3] Institut de Science des Matériaux de Mulhouse CNRS-UMR 7361Université de Haute Alsace, Mulhouse, France; [4] Department of Chemistry Katholieke Universiteit Leuven, Leuven, Belgium.

* *The corresponding author e-mail: franck.camerel@univ-rennes.fr*

The use of organic chromophore thin films in nonlinear optics is growing due to their ease of processing, versatility and tunability, and offers increasing potential in optical communication, optical switching, frequency conversion and more. In particular, SHG organic thin films have attracted considerable interest for data storage due to their potential for high-density information coding.[1] With this in mind, we have developed a strategy for functionalizing 3D organic octupoles with chiral chains to generate non-centrosymmetric liquid crystalline thin films that enable the development of highly active SHG materials without the need for corona poling or tedious deposition techniques (Figure 1, left).[2-4] Recent developments have highlighted the possibility of efficiently encoding data on these SHG-active liquid crystalline thin films by multiphoton absorption, paving the way for 3D optical data storage (Figure 1, right).[5]

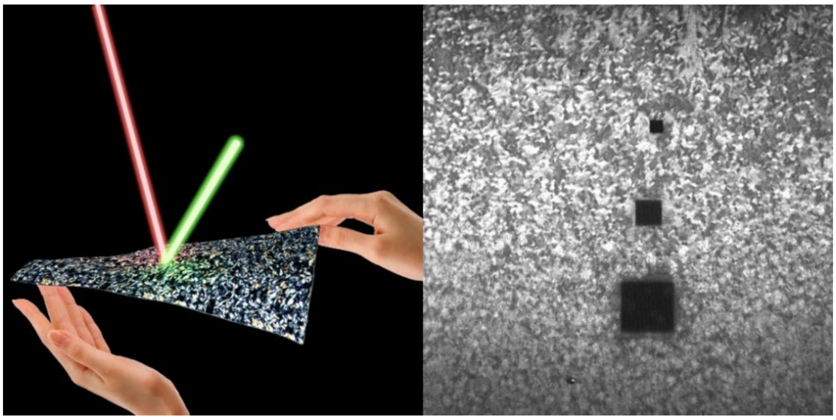


Figure 1: Illustration of the SHG signal emerging from an LC thin film (left), Data recording in an SHG-active liquid crystalline thin film (right).

References

[1] D. Gindre, M. Sallé, *et al. JACS*,**132**, 14343 (2010)

[2] S. van Cleuvenbergen, F. Camerel, *et al.*, *Angew. Chem. Int. Ed.*, **56**, 9546 (2017)

[3] H. Akdas-Kiliç, F. Camerel, *et al.*, *Chem. Eur. J.*, **30**, 1 (2024)

[4] H. Akdas-Kiliç, F. Camerel, *et al.*, *Chem. Asian J.*, **19**, e202400112 (2024).

[5] J.-P. Malval, S. van Cleuvenbergen, F. Camerel, *et al.*, *Adv. Opt. Mater.*, **13**, 2402083 (2025).

Acknowledgments

This work was supported by the ANR (3D-ODS) and the Région Bretagne (3D-STORE).

Stimuli-responsive Liquid-Crystalline phases of metallic nanorods

N. Kutalia[1*], S. Marchand[1], J. G. Trazo[1], J. Marcone[1], P. Davidson[1], M. Imperor-Clerc[1], and C. Hamon[1]
[1] Laboratoire de Physique des Solides (LPS), 91405 Orsay, France
[*] The corresponding author e-mail: nika.kutalia@universite-paris-saclay.fr

Elongated (high aspect ratio) rodlike particles present isotropic to liquid crystal phase transitions upon self-assembly, due to excluded volume interactions.[1] This phenomenon has been witnessed on a variety of systems, including organic (e.g. viruses)[2] and inorganic (e.g. oxides) nanorods but rarely on with metallic nanorods. In this work we demonstrate the existence of liquid crystalline phases (nematic and smectic B) in high aspect ratio Au@Ag (core-shell) nanorods suspensions in water. We combine small-angle x-ray scattering (SAXS) and optical experiments to study the phase behavior of these charged metallic nanorods. Concentrated suspensions align under both electric and magnetic fields, and they show a nematic to smectic B phase transition at sufficiently high electric field. When dispersions were filled into electro-optical LC cells, the nanorods could also be aligned by an electric field, making this system a promising candidate for application in liquid crystalline displays (LCD).

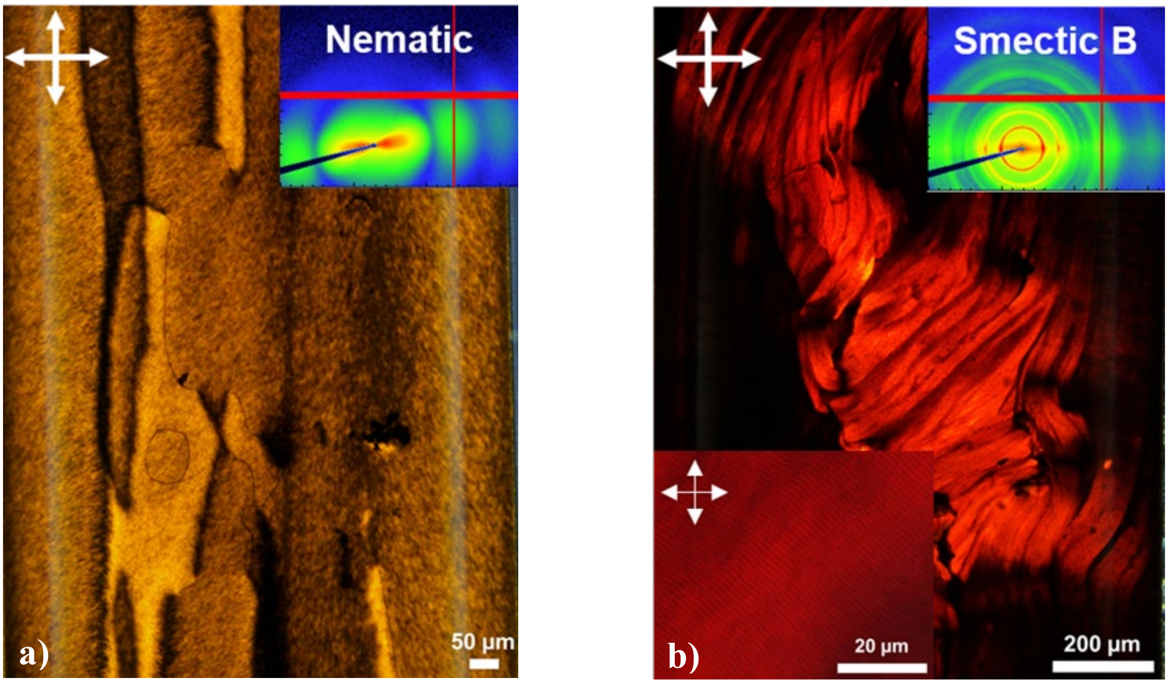


Fig.1: a), and b) Nematic and Smectic B phases (inset: lamellar layers) respectively.

References
[1] P. Davidson, P.C-J. Gabriel, *John Wiley & Sons, Ltd,* **2005**; pp 173–212
[2] H. Anop, L. D. Compare, F. Nallet, A. Giacometti, E. Grelet, *Phys. Rev. Lett.* **134**, 118101

Acknowledgments
This work was supported by the Grant ANR CODENAME (ANR_PRC-CE09). Thomas Bizien is acknowledged for the help during Soleil Synchrotron run.

Reversible nematic/superstructure transitions of metal nanorod-based liquid crystals

J. G. Trazo[1*], N. Kutalia[1], S. Marchand[1, 2], M. Impéror-Clerc[1], P. Davidson[1], C. Hamon[1]

[1] Laboratoire de Physique des Solides, Université Paris-Saclay, CNRS, Orsay 91405, France.
[2] ITODYS, Université Paris-Cité, CNRS, Paris 75013, France.
*jaime-gabriel.trazo@universite-paris-saclay.fr

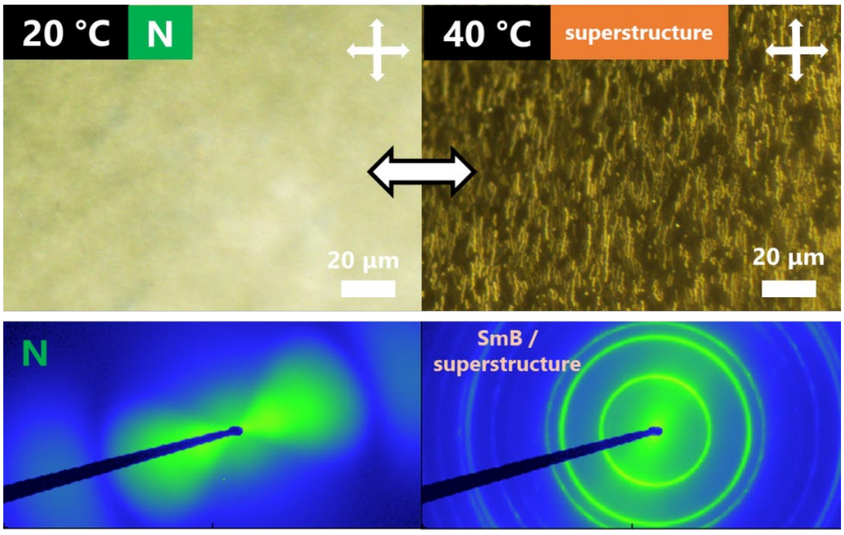


Fig. 1. *Top (POM):* Temperature-induced nematic/needle superstructure transition of aqueous Au@Ag nanorods. *Bottom (SAXS)*: The same transition by tuning depletant concentration.

Reconfigurable optical materials are of key interest in nanoscience. Colloidal micron-long metal nanorods (NRs) coated with CTAC ligands were recently discovered to form an aqueous nematic liquid crystal (LC), which is predicted to be sensitive to depletion forces via addition of CTAC surfactant micelles. While depletion has been previously used to create colloidal NR superstructures with various geometries [1,2], such self-assembly of high aspect ratio rods from LC order is rarely observed.

In this work, we show how such metal (Au@Ag) NR-based LCs can be reversibly condensed and reformed by manipulating CTAC-induced depletion forces, by changing either temperature or depletant concentration. At 20°C, a concentrated metal NR suspension forms a nematic phase, while from 30 to 40 °C, the LC gives rise to extended 1D needle-like superstructures of side-by-side NRs, typically tens of microns long and only one micron wide. These assemblies revert back to the nematic phase upon cooling to room temperature. Similarly, increasing depletant concentration in the system results in a transition between nematic LC order and needle or platelet NR assemblies. By adjusting the depletant concentration, these needles exhibit tunable inter-NR face-to-face separations (from 35 to 5 nm upon increasing [CTAC]) and tunable plasmonic coupling, as demonstrated by surface-enhanced Raman scattering (SERS).

These findings on reversible self-assembly from a LC phase are a new advancement in designing active ‘switchable’ LCs with anisotropic plasmonic properties. Moreover, the formation of these NR superstructures widens our understanding of colloidal self-assembly in anisotropic media.

References

[1] K.L. Young, et al, *PNAS*, **109(7)**, 2240-45 (2012).
[2] B. Sung, et al, *Soft Matter*, **15** (2019).

Acknowledgments

The authors acknowledge the funding of the ANR CODENAME (ANR-23-CE09-0032), and the support of the SWING beamline (SOLEIL Synchrotron).

Probing liquid-crystalline phase transitions using levitated droplets

C. Hotton[1], T. Bizien[2], B. Pansu[1], E. Ferrage[3], C. Hamon[1], E. Paineau[1]
[1]Université Paris-Saclay, CNRS, LPS, 91405 Orsay; [2]Synchrotron SOLEIL, L'Orme des Merisiers, 91192 Gif-sur-Yvette; [3] IC2MP, Université de Poitiers, CNRS, 86073 Poitiers
*erwan-nicolas.paineau@universite-paris-saclay.fr

Self-assembly of liquid crystals is of key relevance for the design of materials with enhanced electrical, electrochemical or optical properties [1]. Evaporation induced self-assembly on various solid substrate has already received a lot of attention providing an easy way to produce nano-assemblies [2]. However, the method suffers from the influence of solid-liquid interface which provide a non-uniform dispersion known as the "coffee-ring" effect. In this context, acoustic levitation appears as a genuine way to self-assemble liquid crystals in a substrate-less environment.

Here, we propose to take advantage of acoustic levitation coupled with Small Angle X-ray Scattering (LevSAXS) to follow in situ the self-organization of 1D and 2D swelling clay minerals in a single levitated droplet [3,4]. The advantage is to track fast non-equilibrium phenomena over a wide concentration range, while avoiding anchoring effects during drying. LevSAXS experiments are carried out during the drying of levitated droplets, revealing the nature of the crystal-liquid phases (columnar, nematic) and enable a complete exploration of the phase diagram with a limited sample volume (one microliter), in less than an hour, moving from a dilute to a highly concentrated state. Our results also reveal a gradual shift from osmotic to crystalline swelling, marked by a transition from a pure nematic glass to a coexistence zone where the nematic phase contracts and a saturated crystalline phase emerges (Figure). This transition occurs through a continuous process, forming interstratified structures ultimately progressing to an unsaturated crystalline state.

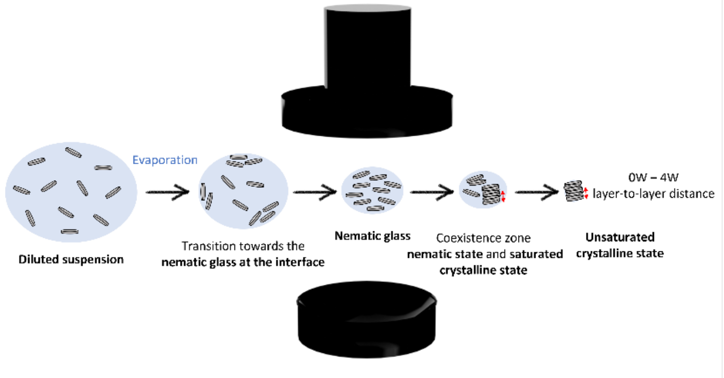


Figure. This scheme summarizes the evolution of the microstructure of smectites from dilute dispersions to the dry state probed by acoustic levitation.

References
[1] K. Thorkelsson, P. Bai, T. Xu, *Nano Today*, **10**, 48-66 (2015)
[2] D. Zang, S. Tarafdar, Y. Y. Tarasevich, M. D. Choudhury, T. Dutta, *Phys Rep*, **804**, 1-56 (2019)
[3] C. Hotton, T. Bizien, B. Pansu, C. Hamon, E. Paineau, *Adv. Mater. Interf.*, **11**, 2400323 (2024)
[4] C. Hotton, T. Bizien, C. Hamon, E. Ferrage, E. Paineau, *Small*, 2505038, (2025)

Acknowledgments
This work had benefited from an Investissements d'Avenir grant from Labex PALM (ANR-10-LABX-0039-PALM).

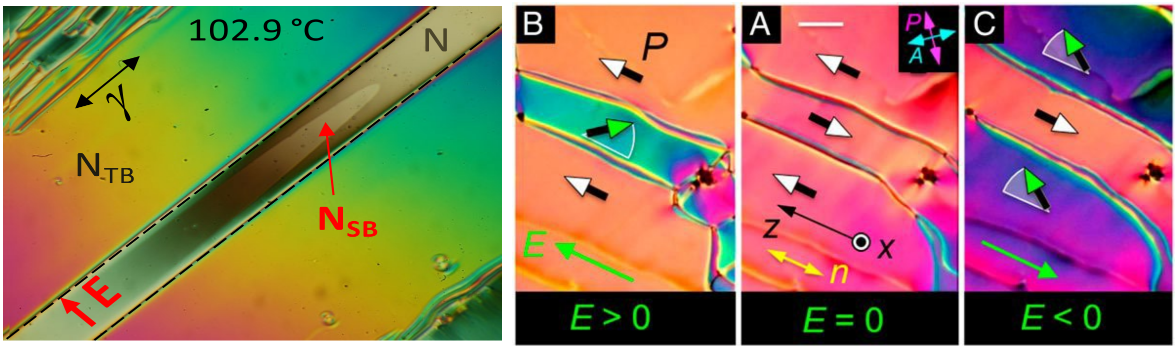
The numerous variants of the nematic phase

P. Davidson
Université Paris-Saclay, CNRS, Laboratoire de Physique des Solides, 91405, Orsay, France
patrick.davidson@universite-paris-saclay.fr

Until recently, the number, nature, and symmetry of liquid crystal phases seemed to be rather well established,[1] and claims of discovery of new mesophases usually described fairly exotic examples. In particular, apart from the usual one, the only known variants of the nematic phase were the chiral nematic (cholesteric), the blue phases, and the biaxial nematic. In comparison, the number of distinct smectic phases of rod-like molecules (SmA, SmB, SmC, SmD, SmE, SmF, …, SmA$_1$, SmA$_2$, SmA$_d$, Sm$\tilde{A}$, …) or that of columnar phases of disc-like molecules (Col$_H$, Col$_R$, …) seemed huge. This significant disparity was tentatively attributed to the pronounced intrinsic molecular disorder of the nematic phase, which would effectively average out any tendency towards local order induced by steric or electronic molecular features.

However, around ten years ago, following previous theoretical predictions, new variants of the nematic phase were identified,[2] namely the “twist-bend” and “splay-bend” nematic phases of bent molecules. As expected, these nematic phases have no long-range positional order, but they display a periodic orientational modulation of the director that is heliconical for the former or planar for the latter. Due to the periodic character of the modulation, these nematic phases show optical textures that are quite similar to those of smectic phases, with which they have been sometimes mistaken.

More recently, the groundbreaking discovery of a ferroelectric nematic phase was reported for a mesogen with a very strong dipole.[3] While the possibility of such a phase has been debated theoretically for over a century, the prevailing view was that the strong molecular disorder of the nematic phase would invariably result in equal numbers of molecules pointing up or down, thereby cancelling out any net electrical polarization. This quite unexpected discovery calls for a complete revision of our understanding, based on symmetry arguments, of the fundamental physics of the nematic phase. It also has far-reaching consequences for LCD applications, as the electric field required to control the alignment of a ferroelectric nematic sample is lower by several orders of magnitude than that needed for a usual nematic sample.



Left: splay-bend nematic (N$_{SB}$) growing, under applied electric field, within the nematic (N) and twist-bend nematic (N$_{TB}$).[4] Right: Behavior of antiparallel domains of the ferroelectric nematic phase under electric field.[3]

References

[1] A.Braslau et al, La diffraction des rayons X par les cristaux liquides, EDP Sciences 2023
[2] M.Cestari et al, *Phys. Rev. E*, **84**, 031704 (2011)
[3] X.Chen et al, *P.N.A.S.*, **117**, 14021 (2020)
[4] C.Meyer et al, *Sci. Adv.*, **6**, eabb8212 (2020)

Acknowledgments: This work was supported by ANR (ANR-23-CE24-0006-03 "DISPLAY").

IN THE SEARCH OF BISTABLE DISPLAYS BASED ON LOW K_3 NEMATIC

Rabab Zehra[1], Ivan Dozov[2], Daniel Stoenescu[3], Christophe Blanc[1], Maurizio Nobili[1]
[1]Soft Matter Physics, Laboratoire Charles Coulomb, University of Montpellier, Montpellier, France;
[2]Laboratoire de Physique des Solides, Université Paris-Sud, Orsay, France;
[3]IMT-Atlantique, Brest, France

Classic Liquid Crystal Displays (LCDs) switch between on/off states under an electric field. However, this field must be continuously applied to maintain the desired state, leading to higher power consumption and making traditional LCDs less suitable for low-energy devices (LECs). Hence, the main motivation of this work is to achieve LECs via cell bistability.

In order to achieve bistability, numerical simulation has been done in Vertically Aligned Nematic (VAN) using different cell thickness over pitch ratios and very low bend elastic constant. These parameters correspond to the nematic phase in the vicinity of the Nematic Twist-Bend (NTB) transition[1]. Numerical results suggest a possible bistability and first-order transitions under electric field. In the experiments, we focus on a VAN cell filled with a binary mixture of 8CB (58 wt%), CB7CB (42 wt%) having positive dielectric anisotropy and slightly doped with a chiral dopant R811 (see fig. 1). Using a spectrometer and the Grandjean-Cano method[2], we measure and control the cell thickness and the pitch respectively, hence the confinement ratio. The first results show that at 10°C above the NTB phase, the initial state with no field corresponds to the Translationally Invariant Cholesteric (TIC). On increasing the electric field normal to the plates, the transmitted intensity under crossed polarizers decreases continuously, indicating a second order transition from TIC to a nematic phase oriented parallel to the field (see fig. 2). Such results will be discussed.

Currently, we are exploring Twisted Nematic cells under external field both experimentally and by numerical simulations. The first results on this new geometry will be discussed.

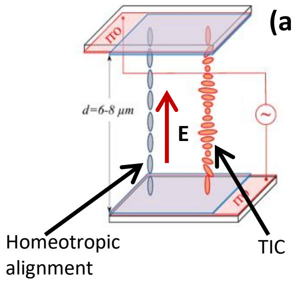


fig. 1

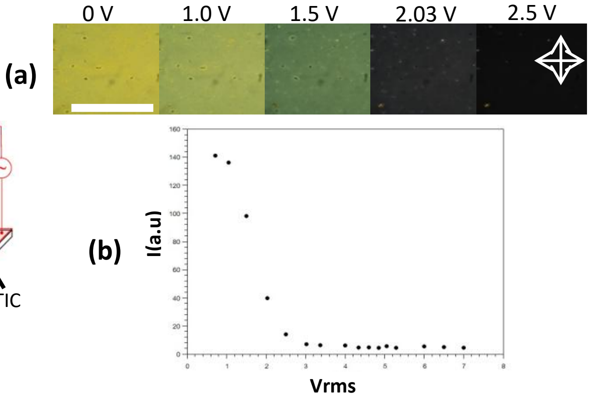


fig. 2

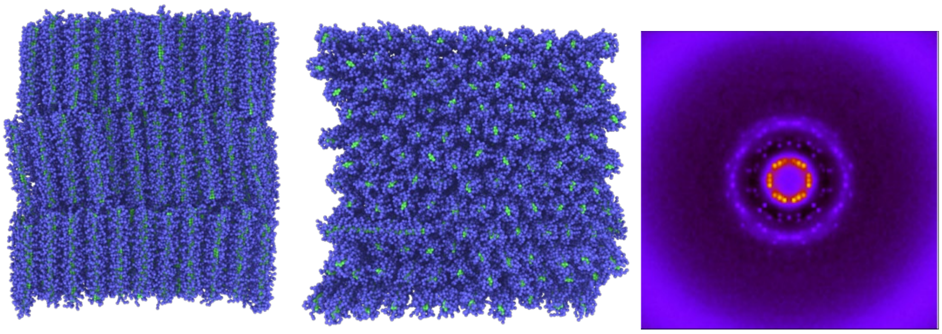
Figure1. Vertically Aligned Nematic (VAN) cell showing liquid crystal alignment with and without electric field. Figure2: (a) Liquid crystal texture with increasing voltage (white scale bar 100 µm); (b) Transmitted Intensity (I) vs voltage (V), corresponding to the textures in (a).

(1) Dozov, I. On the Spontaneous Symmetry Breaking in the Mesophases of Achiral Banana-Shaped Molecules. *Europhys. Lett. EPL* **2001**, *56* (2), 247–253. https://doi.org/10.1209/epl/i2001-00513-x.
(2) Podolskyy, D.; Banji, O.; Rudquist, P. Simple Method for Accurate Measurements of the Cholesteric Pitch Using a "Stripe–Wedge" Grandjean–Cano Cell. *Liq. Cryst.* **2008**, *35* (7), 789–791. https://doi.org/10.1080/02678290802175756.

Complex Smectic Phases in Polymer Grafted Colloidal Nano-Crystals

William S. Fall[1], Henricus H. Wensink[1*]

[1]Laboratoire de Physique des Solides – UMR 8502, CNRS, Université Paris-Saclay, 91405, Orsay, France
**Corresponding author e-mail:* rik.wensink@cnrs.fr



The effect of short chain grafting on the lyotropic liquid crystalline ordering of colloidal nano-crystals is investigated using coarse-grained molecular dynamics simulations [1]. Nano-rods with aspect ratios of typical of cellulose nano-crystals (CNCs) are considered and grafted randomly with short oligomers of length 4 beads at 5 different grafting densities. All systems are crystallised from the isotropic phase in implicit dilute solution and slowly compressed until spontaneous ordering of the nano-rod backbones occurs. The liquid crystalline ordering is observed to depend heavily on the grafting density as the effective shape and softness of the nano-rods is modified through polymer grafting. Ungrafted rods exhibit complex biaxial Nematic and Smectic-C phases at very low volume fractions, which are then preserved upon grafting with at least a 50% occupation of surface sites with polymers, forming a Nematic and a tilted Smectic-I phase. Heavier grafting results in further anisotropy and the disappearance of the Nematic phase and a direct transition to a complex Smectic-B. Interesting behaviour is observed at extremely low grafting densities, around 25%, with the disappearance of the Smectic phases and a persistent Nematic phase induced by patchy grafting which transitions to a Lamellar phase. Such systems fall outside of the traditional hard or soft rod descriptions of phase-transitions in rod-like LC systems. Our findings point to as yet undiscovered LC behaviour in monodisperse systems of both grafted and ungrafted rod-like nanocrystals.

References

[1] W.S. Fall and H. H. Wensink, *Macromolecules* **57**, 8957 (2024)

Acknowledgments

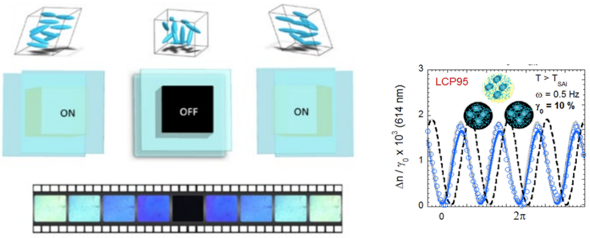
This work was supported by the European Innovation Council (EIC) through the Pathfinder Open grant “INTEGRATE” (no. 101046333). We gratefully acknowledge access to the HPC resources of IDRIS under the allocation 2022-A0130913823 made by GENCI.

The isotropic phase: the “Sleeping Beauty” of LCs that reveals hidden mesoscopic liquid properties

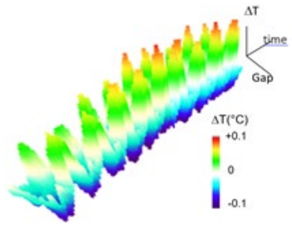
L Noirez[1*]
[1]*Laboratoire Léon Brillouin (CEA-CNRS), Université Paris-Saclay, 91191 Gif-sur-Yvette Cédex, France*
[*] laurence.noirez@cea.fr

On basis of the Maxwell model for simple liquids, it has long been assumed that the isotropic phase of liquid crystals does not possess long range correlations. Fascinating flow induced phase transitions have however been identified revealing the emergence of long range collective dynamic behaviors in the isotropic phase. Moreover, a synchronic strain induced birefringence is also appearing by applying low frequency (Hz) oscillatory shear (Fig.1) [1].

These theoretically unexpected effects are now explained on basis of the excitation of mesoscopic shear elasticity (solid-like property). As consequence, molecules are not free in the isotropic phase [1]. Firstly identified by the behavior the isotropic LC phase, liquid elasticity is now identified at a generic small scale property of simple and complex fluids (polymers, micellar solutions, ionic liquids, H-bond liquids…). While early evidence of the solid-like property by the renowned physicist, B.V. Derjardin [2], was met with skepticism, it appears now that mesoscopic liquids are long range interacting systems. This view is in agreement with several new atomistic theoretical frameworks confirming that the existence of a finite shear modulus [3]. Mesoscopic (shear) elasticity has profound implications on flow, surface instabilities, thermodynamics, fluidic transport mechanisms and makes possible the identification of new liquid properties like thermo-elasticity (Fig.2)[4], solid-liquid phonon coupling or spectacular optical LC conversions in harmonic oscillators [1]. Exploring the non-equilibrium isotropic phase has shown that correlations are not lost, that collective non-dissipative properties are preserved, instilling hope for a better understanding of the liquid state.



1.



2.

Fig.1: Exciting the isotropic phase of some LCs with a low frequency oscillatory motion stretches elastic correlations so far neglected (real snapshots recorded crossed polarizers [1]). Fig.2: Real-time micro-thermal mapping revealing that confined liquids (here PPG) emit a synchronous thermal signal when stretched by low-frequency shear stress (~Hz) [4].

References

[1] P.Kahl, P. Baroni, L. Noirez, *Appl. Phys. Lett.* 107, 084101 (2015).

[2] B.V. Derjaguin, U .Bazaron, K. Zandanova, O. Budaev, O. The complex shear modulus of polymeric and small-molecule liquids. *Polymer* 30, 97 – 103 (1989).

[3] Zaccone, A.; Trachenko, K. Explaining the low-frequency shear elasticity of confined liquids. *Proceedings of the National Academy of Sciences* 117, 19653–19655 (2020).

[4] E. Kume, P. Baroni & L. Noirez, Strain-induced violation of temperature uniformity in mesoscale liquids. *Scientific Reports* 10, 13340 (2020), doi: 10.1038/s41598-020-69404-1.

Acknowledgments: This work is dedicated to the memory of Patrick Baroni.

Experimental generation of optical shock waves in nematic liquid crystals

J. F. Henninot[1*] et E. Louvergneaux[2]
[1] Université Artois, CNRS, UMR 8181 - UCCS - Unité de Catalyse et de Chimie du Solide, F-62307 Lens Cedex, France, [2] Université Lille, CNRS, UMR 8523 - PhLAM - Physique des Lasers Atomes et Molécules, F-59000 Lille, France
**E-mail : jfrancois.henninot@univ-artois.fr*

We show that it is possible to generate an optical shock wave during the propagation of an optical wave in a focusing Kerr medium thanks to an appropriate initial condition. This corresponds to a spatial discontinuity of the "stair step" type on the intensity profile of the injected wave. During propagation in a nematic liquid crystal film, this will "print" a jump on the refractive index which will give rise to the shock. This strategy is well known in nonlinear optics when the nonlinearity is of the defocusing type since the system is then equivalent to what happens in hydrodynamics in shallow water with the emergence of undulating jumps. These undulations, known as tidal bore or dispersive shock wave, result from the "regularization" of the discontinuity between the two water levels. However, when the nonlinearity is of the focusing type, the presence of modulation instability complicates the dynamics since it competes with shock dynamics.

By exploiting the nonlocal nature of our nonlinearity to reduce the development of modulational instability, we demonstrate that shock dynamics prevail over modulational instability. The shock dynamics obtained are similar to those observed in hydrodynamics. Indeed, the optical wave propagation distance Z_s required for the shock to occur follows a power law with the beam power P such that $Z_s \propto P^{-4/3}$. Finally, we demonstrate that the nonlocal response of the nonlinearity is responsible for the curvature of the jump trajectory, which opens a path for optical beam routing.

Keywords: Optical shock, self-stiffening, discontinuity, nonlinear optics, nonlocal response, photonics, nematic liquid crystals.

Références

[1] A. Aleksanyan, H. Louis, J. F. Henninot, E. Louvergneaux, Phys. Rev. E, **103**, 022701 (2021)

Stabilizing Blue-Phase Liquid Crystals Using Gold Nanoparticles

Xintao Zheng[1], Tobias Thiele[2], Claire Abadie[1], Sébastien Royer[1],Bruno Gallas[1], Yoann Prado[1], Austin Hubley[5],Rodrigo Hernández Ochoa[4], Theyencheri Narayanan [5], Alexey Eremin[3], Michael Giese[2], Linda Reven[4],Mark Sutton[4],Emmanuelle Lacaze[1*]

[1]CNRS, Institut des Nanosciences de Paris, INSP, Sorbonne Université, 4 place Jussieu, PARIS Cedex 05, France; [2]Faculty of Chemistry, Organic Chemistry, University of Duisburg-Essen, Universitätsstrasse 7, 45117 Essen, Germany; [3]Otto-von-Guericke-Universität Magdeburg, FNW/IEP/ANP, Postfach 4120, 39016 Magdeburg, Germany.;[4]Department of Chemistry, Faculty of Science, McGill University, 845 Rue Sherbrooke O, Montréa, Canada
[5]ID02 Beamline，European Synchrotron Radiation Facility – ESRF, 71 Av. des Martyrs, 38000 Grenoble,France

[*] *The corresponding author e-mail: emmanuelle.lacaze@insp.jussieu.fr*

Blue phase liquid crystals (BPLC) are self-organized double twisted cholesteric liquid crystal (CLC) materials exhibiting a Bragg-type selective reflection. Various blue phases (BP) are observed in a small temperature range between the isotropic and the cholesteric phases of CLCs with relatively short pitch [1]. During cooling, three types of BPs are formed depending on the chirality of LC: blue phase III (BP-III), BP-II, and BP-I [2], [3], [4], BP-III is characterized by double twisted cylinders (DTC) with random orientation, while BP-II and BP-I are three-dimensionally ordered simple cubic (SC) and body-centered (BCC) crystals of DTC, respectively. In BP-II and BP-I, discontinuous points exist where the DTCs are in contact, and DTCs and disclination defects coexist [5].

BP have a great technological potential but a main limitation of application by narrow temperature range. Stabilization of the blue phase could be achieved by using molecules with hydrogen bonds [6], mixed with polymers [7] or mixed with nanoparticles (NPs) [8]. The reduction of the energy penalty created by the disclinations can indeed be achieved by filling them with NPs, which leads to the stabilisation of the composite material and the widening of the temperature range. However, a more comprehensive understanding of the temperature stabilisation is still not given, in particular in terms of the role of the size and functionalization of the NPs. Moreover, the use of NPs brings the additional value of the intrinsic properties of the NPs which allow to build a composite material (BPLC-NP) with new properties. This concerns for example the plasmonic properties of gold NPs.

This work examines how varying concentrations of gold nanoparticles (GNPs) influence the phase behavior of blue phase liquid crystals (BPLCs), specifically using the DFP ($St4_{50}/St_{50}$) material system. GNPs with diameters of 3, 4.5, and 5 nm were incorporated into the isotropic phase of the BPLC mixture. After complete evaporation of the toluene solvent, a uniform BPLC–GNP composite was obtained. The phase transition behavior was characterized using reflection-mode optical microscopy, revealing that the temperature range of the blue phase broadened systematically with increasing GNP concentration. This observation indicates a clear stabilizing effect of GNPs on the BPLC structure, dependent on their concentration.

To gain deeper insight into the structural and optical effects of GNP incorporation, small-angle X-ray scattering (SAXS) was performed at the ESRF ID02 beamline. The scattering results show that GNPs are randomly dispersed within the blue phase lattice, yet still contribute significantly to the structural stability of the liquid crystal. Complementary spectroscopic ellipsometry measurements were carried out to assess the impact on optical properties, while electric field experiments were used to probe optoelectronic responses. Overall, the presence of GNPs not only enhances the thermal stability of the blue phase—extending its range from 8.3 °C to 10.2 °C—but also provides a pathway for tuning the optical and electro-optical performance of BPLC-based photonic materials.

References

[1] Thoen, J. *Physical Review A,* 37(5), 1754 (1988)
[2] Castles F, Day F V, Morris S M, *Nature materials* 11.7, 599-603 (2012)
[3] Kikuchi H, Yokota M, Hisakado Y,*Nature materials,* 1(1), 64-68 (2002)
[4] Coles H J, Pivnenko M N. *Nature,* 436(7053), 997-1000 (2005)
[5] Meiboom S, Sammon M. *Physical Review Letters*, 44(13): 882, (1980)
[6] Saccone M, Spengler M, Pfletscher M, *Chemistry of Materials*, 31(2), 462-470 (2019)
[7] Kikuchi H. *Liquid crystalline functional assemblies and their supramolecular structures,* 99-117 (2008)
[8] Yoshida H, Tanaka Y, Kawamoto K,*Applied physics express*, 2(12), 121501 (2009)

Acknowledgments

This work was supported by CHINA SCHOLARSHIP COUNCIL（CHINA）& INSP, Sorbonne University

From Chirality to Helicity in Biological Liquid Crystals

E. Grelet[1*]
[1] *Centre de Recherche Paul-Pascal, CNRS & Université de Bordeaux, France*
[*] *The corresponding author e-mail: eric.grelet@crpp.cnrs.fr*

Chirality is ubiquitous in Nature, and it exists across all observable length scales, starting from the molecular level where broken enantiomeric symmetry in L-amino acids and D-sugars can generate helical secondary structure in proteins and DNA, and through to the supramolecular level where it creates macroscopic chiral architectures including most of living matter [1]. These chiral morphologies are significant not only in biological systems, but have important implications for materials and nanoscience, including photonics, enantiomeric separation, optoelectronics and sensors.

The key question of how chirality propagates from nanoscale building blocks to high-order helical assemblies such as the cholesteric liquid crystalline phase remains a major open issue, despite many investigations over the past decades [1-3]. In this presentation, we will discuss recent results on hierarchical propagation of chirality—that is, the causal relationship between the microscopic properties of molecular building blocks and their emergent macroscopic structure. We will mostly focus on biological systems, including, among others, DNA [2,4], filamentous viruses [5], collagen fibrils [6] and cellulose nanocrystals [7].

We will highlight the ways in which supramolecular helicity rise from subtle chiral contributions of opposite handedness that act either cooperatively or competitively, thus accounting for the multiplicity of chiral behaviors observed in nature [5].

References

[1] M. Mitov, *Soft Matter*, **13**, 4176 (2017).
[2] M. Siavashpouri, C. H. Wachauf, M. J. Zakhary, F. Praetorius, H. Dietz, Z. Dogic, *Nature Materials*, **16**, 849 (2017).
[3] B. Sung, A. de la Cotte, E. Grelet, *Nature Communications*, **9**, 1405 (2018).
[4] M. M. C. Tortora, G. Mishra, D. Prešern, & J. P. K. Doye, *Science Advances*, **6**, eaaw8331 (2020).
[5] E. Grelet, M. M. C. Tortora, *Nature Materials*, **23**, 1276 (2024).
[6] M. Robin, C. Djediat, A. Bardouil, N. Baccile, C. Chareyron, I. Zizak, P. Fratzl, M. Selmane, B. Haye, I. Genois, J. M. Krafft, G. Costentin, T. Azaïs, F. Artzner, M.-M. Giraud-Guille, P. Zaslansky & N. Nassif, *Advanced Science*, **11**, 2304454 (2024).
[7] T.G. Parton, R. M. Parker, G. T. van de Kerkhof, A. Narkevicius, J. S. Haataja, B. Frka-Petesic & S. Vignolini, *Nature Communications*, **13**, 2657 (2022).

Light mediated swimming regimes in cholesteric liquid crystal droplets

G. Ramos[1*], G. Li[2], C. Roux[1], J.D. Marty[1], V. Pimienta[1], M. Maisonneuve[2], R. Métivier[2], C. Coudret[1], J. Xie[2]
[1]*Laboratoire Softmat, Université de Toulouse, CNRS UMR 5623, 31062 Toulouse, France*
[2]*PPSM, ENS Paris-Saclay, CNRS, Université Paris-Saclay, 91190 Gif-sur-Yvette, France*
[*]*gabriel.ramos-peroni@utoulouse.fr*

Chemically active droplets, particularly liquid crystal (LC) droplets, have emerged as a significant area of study within the field of active matter [1]. These droplets exhibit self-propulsion and complex behaviors, such as chemotaxis or light sensing, which are crucial for understanding the fundamental principles of active systems and for developing novel applications in materials science and biotechnology. The propulsion mechanism of LC droplets is primarily driven by the Marangoni effect. This effect generates fluid flows due to gradients in surface tension, enabling the droplets to swim autonomously (Fig. 1a-inset). A fascinating aspect of these LC droplets is the interplay between their internal LC order and Marangoni flows, leading to different swimming regimes. On the other hand, the development of new types of photosensitive chiral dopants has paved the way for precise control over the cholesteric order of liquid crystals [2]. In this work, we made photo-cholesteric liquid crystal (P-CLC) droplets using 4-Cyano-4'-pentylbiphenyl (5CB) and a new synthesized photosensitive chiral dopant. We show that under the action of light (365 nm and 415 nm) the chiral dopant is isomerized, leading to changes in the cholesteric pattern of the droplets (Fig. 1a), that in turn, leads to a change in the droplet's swimming regime (Fig. 1b). These results allow for better regulation of the swimming patterns and enables the guidance of droplets through an optical landscape (Fig. 1c). Such control opens up new possibilities for manipulating active matter systems with high precision, potentially leading to innovative technologies and applications.

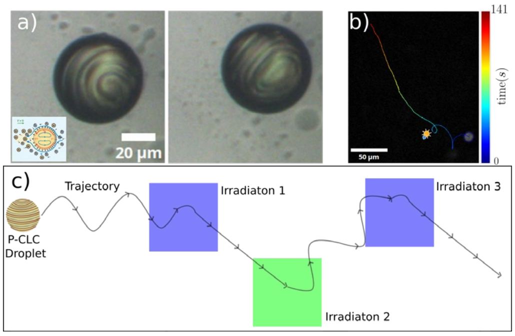


Figure 1: a) P-CLC droplet before irradiation (left) and after irradiation (right). A change in the cholesteric pattern is observed. Inset: Marangoni effect, driving the droplet's movement. b) Change in swimming regime under irradiation. The colored line is the droplet's trajectory, and each color represents the time. The moment of the irradiation is represented by the light-bulb. c) Optical landscape. The guidance of the droplet can be achieved by sequentially irradiating at different points in space, and thus changing the swimming regime regarding the required direction. Inset in a) is modified from [1].

References
[1] S. Michelin, *Annual Review of Fluid Mechanics*, **55**, 77-101 (2023)
[2] Y. Kim, N. Mafy, S. Maisonneuve, C. Lin, N. Tamaoki, J. Xie, *ACS Appl. Mater. Interfaces*, **12**, 52146-52155 (2020)

Acknowledgments
This work was supported by the French National Research Agency (project No. ANR-23-CE06-0022 HELISWEETCH).

From Lehmann clusters through tangles to bangles

P. Pieranski[1*], M. Zeghal[1], P. Judeinstein[2]
[1] Laboratoire de Physique des Solides, Université Paris Saclay, Orsay, France
[2] Université Paris-Saclay, CEA, CNRS, LLB, 91191 Gif-sur-Yvette, France

[*] *The corresponding author e-mail: pawel.pieranski@universite-paris-saclay.fr*

Cholesteric dislocations with the Burgers vector b equal to the cholesteric pitch p are analogous to the S=1 disclinations in nematics ; their director field is nonsingular thanks to the escape into the third dimension. In cholesterics, the two nonsingular director fields resulting from the two modes of the escape into the 3rd dimension (see Figures 1b and 1c) are related by a π rotation around the horizontal axis orthogonal to the dislocation line.

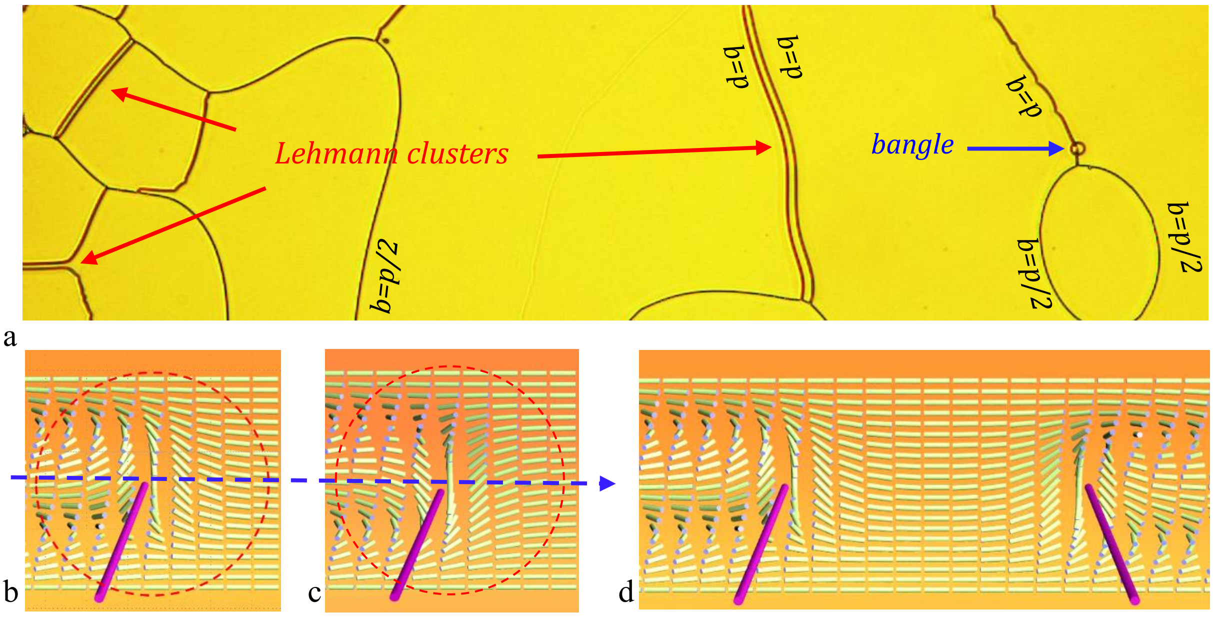


Figure 1: Escape into the 3rd dimension of the b=p dislocations in cholesterics. a) Lehmann clusters and bangles in a sample of 5CB/CB15 with the pitch p=90µm confined in a gap of thickness h=110µm. b-c) The two possible modes of the escape into the 3rd dimension. d) The Lehmann cluster.

Pairs of the escaped dislocations of the same type, defined in Figure 1d, are immune against coalescence so that they form stable *Lehman clusters* observed in experiments (see Figure 1a). For the same reason, the nonsingular b=p dislocations form *bangles* tethered on kinks of *cargo* loops (see Figure 1a) or tangles [1], knots and links [2].

References

[1] P. Pieranski, M. Zeghal, M. Godinho, P. Judeinstein, *Phys. Rev. Lett.* **131**, 128101 (2023).
[2] P. Pieranski, M. Godinho, *Liq. Cryst.* **51**, 1-32 (2024).

Self-Engineered Tunable Phase Masks for High-Contrast Imaging

N. Kravets and E. Brasselet

Université de Bordeaux, CNRS, Laboratoire Ondes et Matiere d'Aquitaine,
F-33400, Talence, France.
[*] *The corresponding author e-mail:* nina.kravets@u-bordeaux.fr

The ability of liquid crystals of self-organization into complex topological structures offers a unique route to accessible engineering of functional optical elements. In uniformly aligned nematic layers subjected to uniform external electric field, pairs of umbilic defects spontaneously emerge due to symmetry breaking. They normally evolve via mutual interactions and annihilation but can be localized using additional structured fields. We will present our recent advancements in the controlled generation and stabilization of isolated topological defects using structured fields in vertically aligned nematic cells. Notably, we will show how these self-engineered defects can be precisely tuned in terms of core size, spatial extent, and topology, enabling the development of tunable liquid crystal-based optical components.

We particularly explore the application of such defects in high-contrast imaging systems, focusing on their integration into vector vortex coronagraphs. Unlike conventional sub-wavelength structured masks or polymer-stabilized liquid crystals, umbilic topological defects offer inherent wavelength tunability and fine spatial control, addressing key limitations in current coronagraph designs. Our findings indicate that nature-assisted engineering of these liquid crystal masks offers a simple and accessible approach to creating broadband-tunable optical phase elements. These components may hold particular appeal for the amateur astronomy community, offering a practical balance of performance and simplicity without requiring advanced fabrication techniques.

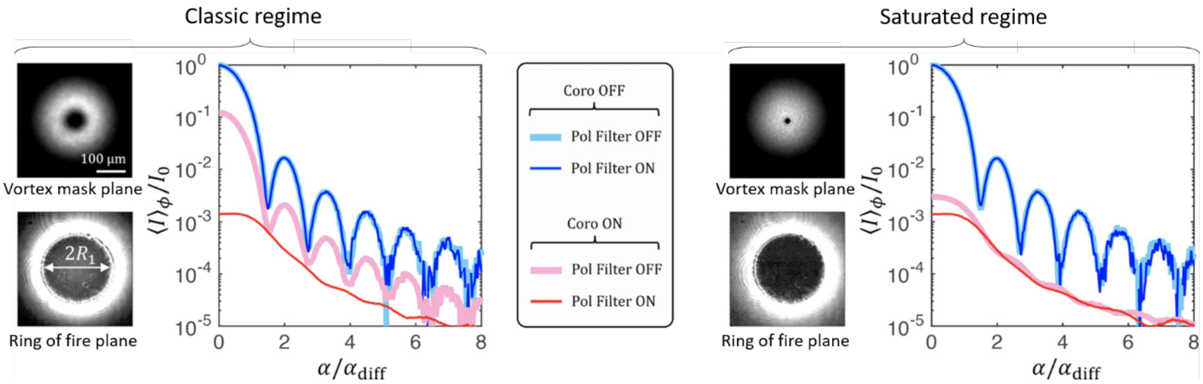


Figure 1. Improved coronagraph performance with umbilic defect in saturated (far from Fréedericksz transition) regime. Figure adapted from [2].

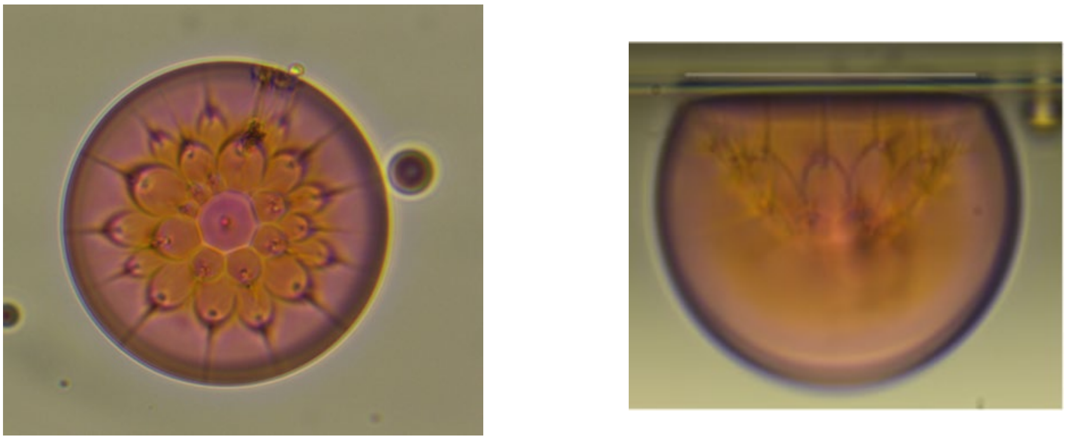
References

[1] A Aleksanyan, N Kravets, E Brasselet *Phys. Rev. Lett*. **118**, 203902 (2017)
[2] N Kravets, U Mur, M Ravnik, S Žumer, E Brasselet, *Appl. Phys. Lett*. **121**, 241104 (2022)

Floral architecture in sessile cholesteric droplets

B.Pansu[1*], Y. Nastishin[2], R. Kamien[3]
[1] Universite Paris-Saclay, CNRS, Laboratoire de Physique des Solides, UMR-8502, 91405, Orsay, France; [2] Hetman Petro Sahaidachnyi National Army Academy, Lviv, Ukraine; [3] Department of Physics and Astronomy, University of Pennsylvania, 209 South 33rd Street, Philadelphia, Pennsylvania 19104, USA
[*] The corresponding author e-mail: brigitte.pansu@universite-paris-saclay.fr

A remarkable three-dimensional architecture built spontaneously by defects in a cholesteric drop placed on a flat surface has been revealed through optical microscopy. The conditions under which the cholesteric layers are anchored on the flat surface and at the interface of the drop with the surrounding medium give rise to focal domains based on ellipses distributed on a paraboloid within the drop. These focal domains are organized in an elegant 3D geometric architecture, of which a complete model is proposed.



a) b)

Cholesteric droplet in glycerol seated on a glass surface
observed by optical microscopy: a) top view, b) side view

References

[1] R. D. Kamien, Y. Nastishin, B. Pansu, *Proc Natl Acad Sci USA*, **120(46),** 2311957120 (2023)

Etude de l'évolution d'une désinclinaison à la transition de phase N/SmA

Vincent Plée*, Christy Kate Mbadinga , Marie Giacomini , Alex Crimet , Roll Freddy Dimeni, Randa Mrad, Issyan Tekaya, D. Raingard, Gianni Pascoli , Claire Meyer

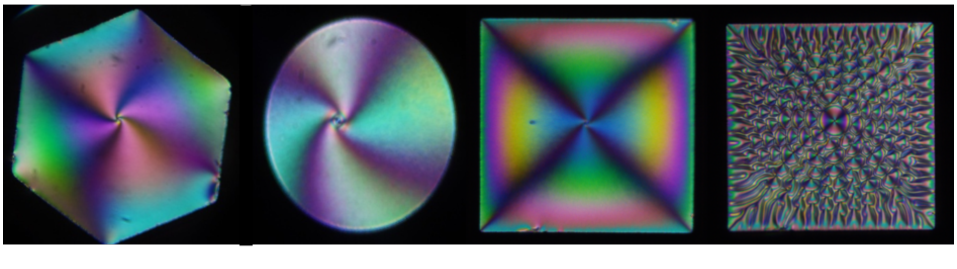
Physique des Systèmes Complexes - Université de Picardie Jules Verne
Université de Picardie Jules Verne - 33, rue Saint-Leu - 80039 Amiens cedex 1 - France

---

Les cristaux liquides présentent, dans certaines conditions, des défauts topologiques observables en microscopie optique polarisée. Dans la phase nématique (N), les molécules sont en moyenne dirigées selon le directeur **n**. Les discontinuités d'orientation du directeur, ou désinclinaisons -classifiées par F. C. Frank [1]- sont observables expérimentalement ; ce sont celles dont les rangs m sont les plus petits (m=±1, ±1/2) qui sont le plus souvent observées car l'énergie associée à ces défauts est quadratique en m. Dans la phase Smectique A (SmA), les molécules présentent, en plus d'un ordre d'orientation, un ordre de position de leur centre de gravité au sein des couches parallèles. Le directeur est alors dirigé selon la normale aux couches. Les défauts macroscopiques sont constitués d'ellipses et d'hyperboles confocales, appelés coniques focales [2].

On cherche à comprendre comment une désinclinaison nématique de rang m=1 ou m=-1 se transforme à la transition N/SmA lorsque l'on diminue très lentement la température. Pour ce faire, on dépose une goutte de 8CB sur une grille de microscopie électronique [3] possédant un maillage de trous de différentes formes géométriques (hexagonales, circulaires, carrées) au centre desquels on observe une désinclinaison unique. On s'intéresse à l'effet éventuel de la forme du trou sur l'évolution de cette désinclinaison.

En descente en température, à la transition N/SmA, on constate l'apparition de stripes [4] à partir de la ligne de désinclinaison puis d'assemblées de coniques focales ; ensuite, les coniques focales disparaissent progressivement presque toutes sauf une, qui rappelle exactement l'endroit où la désinclinaison préexistait. Cette dernière conique focale disparaît finalement à son tour laissant un champ d'observation complètement homogène. Des mesures de biréfringence nous permettent d'une part de reconstruire le champ de directeur et d'autre part de vérifier le profil en épaisseur du film.



[1] F. C. Frank, Discuss. Faraday Soc. **25**, 19 (1958).
[2] M. Kleman and O. D. Lavrentovich, Soft Matter Phys. An Introduction, Wiley New York (2003).
[3] V. Plée, J. Lacam, G. Pascoli, C. Meyer, Materials **18**, 711 (2025). https://doi.org/10.3390/ma18030711.
[4] P.E. Cladis, S. Torza, J.Appl.Phys.**46**,584-599(1975).

Light guiding within cholesteric topological patterns

G. Poy[1,2*], S. Žumer[3,4]
[1]L2C, Univ Montpellier, CNRS, Montpellier, France; [2]International Institute for Sustainability with Knotted Chiral Meta Matter (WPI-SKCM2),
Hiroshima University, Higashi-Hiroshima, Hiroshima 739-8526, Japan; [3]Jožef Stefan Institute, Jamova cesta 39, 1000 Ljubljana, Slovenia; [4]Faculty of Mathematics and Physics, University of Ljubljana, Jadranska 19, 1000 Ljubljana.
[*]guilhem.poy@umontpellier.fr

The past 15 years have seen the emergence of powerful experimental techniques enabling the patterning, control, and optical coupling of localized birefringent structures in liquid crystal (LC) systems. More often than not, these localized patterns of orientational order have a topological nature---they can be classified with integers similar to the genus classification of surfaces---and are stabilized by chirality---the breaking of the mirror symmetry. In particular, the concept of "topological solitons", a localized field pattern that cannot be continuously deformed into the lowest energy state of the system, is especially useful to understand the structure of these patterns. Thanks to their birefringent nature, these patterns also have strong light-matter interactions, including non-linear optical effects accessible at laser powers of a few mW and a wide array of beam shaping and guiding capabilities.

Modelling the structural and optical properties of these structures can however be challenging due to the wide range of scales involved, from the ~10 nm size of singular topological defects and the wavelength size of light up to the pattern size, that can be as big as 0.1-1mm. Based on recent numerical advances allowing to adresse some of the challenges behind these multiscale and multiphysics simulations [1-4], I will present an overview of the waveguiding properties of nonsingular topological patterns that nature offers for free in chiral liquid crystals.

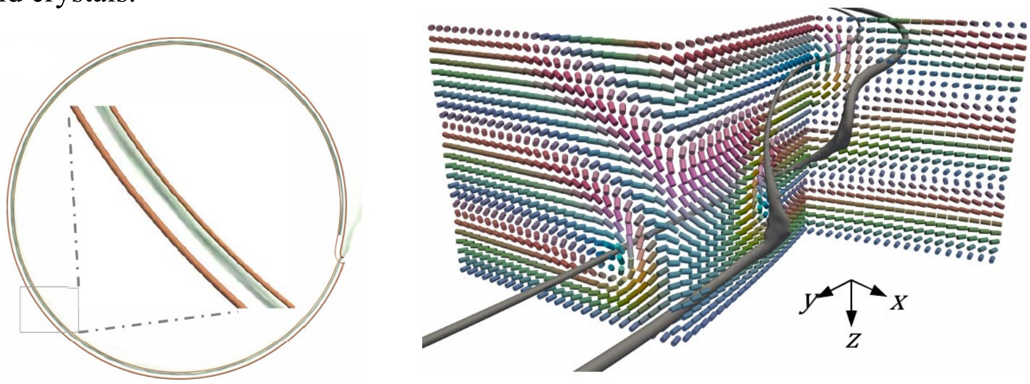


Fig. 1 (left) Guiding light with cholesteric disclination loops. (right) Schematic of the helical layer structure near a nonsingular disclination kink.

References
[1] G. Poy, S. Žumer, S*oft Matter* **15**, 2659 (2019).
[2] G. Poy et al., *Physical Review X* **10**, 031042 (2020).
[3] G. Poy, S. Žumer, *Optics Express* **28**, 24327 (2020).
[4] G. Poy et al., *Nature Photonics* **16**, 454 (2022).

Acknowledgments
G. Poy acknowledges support from the ANR (JCJC project CHIRALGHOST).

Fluctuating dynamics and structure of torons in confined chiral liquid crystals

I. Nurlu*, M. Nobili, G. Poy
L2C, Univ Montpellier, CNRS, F-34070 Montpellier, France
* *idris.nurlu@umontpellier.fr*

Chirality has been shown to play a significant role in soft matter systems, influencing pattern formation, optical activity, and self-assembly. Here, we focus on a particle-like structure called 'toron' [1], which forms in confined cholesteric liquid crystals due to the competition between chirality-induced frustration and elasticity. This structure corresponds to an in-sample-plane baby-skyrmion pattern (*Fig. a.*) embedded in a three-dimensional configuration. A typical microscope image of this structure is shown in *Fig. b*.

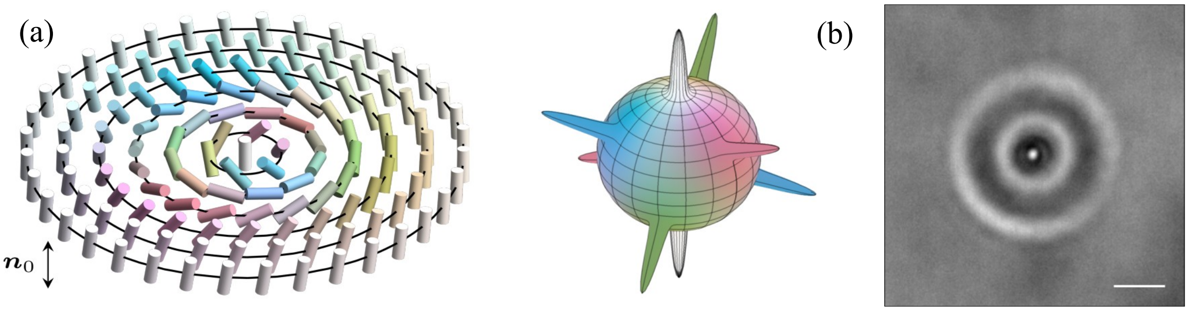


Fig (a) Computer-simulated in-plane director field of the toron from [2]. (b) Natural light microscopy image of the toron. The white bar represents 50 µm .

Thermally-induced fluctuations in the director field induce not only deformation in the toron shape but also translational dynamics, similar to the dynamics of soft Brownian particles. We have developed a setup that combines microscopy observations with in-house data analysis codes to highlight the sub-diffusive behaviour of these topological objects at short lag times. Additionally, we analyse the shape deformations of torons using light-scattering techniques and direct space correlation calculations, showing that these deformations are dominated by a single fluctuation mode. Finally, by adjusting the oven temperature and the voltage applied to the sample, we were able to explore these behaviours near the critical region before the well-known destabilization into cholesteric fingers [3].

References :
[1] I. I. Smalyukh, Y. Lansac, N. A. Clark, R. P. Trivedi, Nature materials, 9, 139-145 (2010)
[2] G. Poy, A. J. Hess, A. J. Saracuse, M. Paul, S. Zumer, I. I. Smalyukh, Nature Photonics 16, 454–461 (2022)
[3] P. Oswald, P. Pieranski, Nematic and cholesteric liquid crystals, CRC press, Boca Raton (2005)

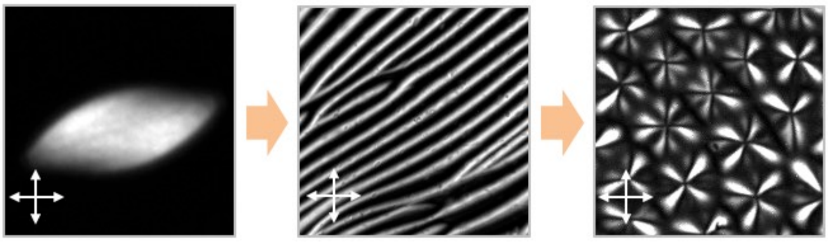
Acknowledgments
This work was supported by the ANR (project No. 23-CE06-0016).

Morphogenesis and Topological Evolution of Nematic Colloids under Confinement

Lilian Magermans[1], Jeongmo Kim[1], Reinaldo Chacon[2], Aymeric Leray[2], Timothy Atherton[3],
Thierry Gacoin[1] and Jongwook Kim[1]*

[1]Laboratoire de Physique de la Matière Condensée – CNRS, Ecole Polytechnique, Institut Polytechnique de Paris, Palaiseau, France; [2]Laboratoire Interdisciplinaire Carnot de Bourgogne – CNRS, Université de Bourgogne, Dijon, France.

* *The corresponding author e-mail: jong-wook.kim@polytechnique.edu*



Phase transition and morphogenesis of typical liquid crystals occur at rapid timescales (submillisecond) and small length scales (submicron), leaving these dynamic phenomena largely unexplored. In this presentation, we report a novel morphogenesis process from nematic tactoids to never-before-seen flower-shaped structures, by using a colloidal LC composed of Eu^{3+}-doped $LaPO_4$ nanorods [1]. We demonstrate 3D orientational tomography of the structure based on polarizing photoluminescence spectroscopy of the Eu^{3+} [2, 3], revealing the complex topology and topographies. Based on the experimental observations and numerical simulations, we find that these flower structures are stabilized by conflicting boundary conditions and relatively weak surface tension compared to the elastic energy [4]. These results provide an experimental insight into the interplay of volume and surface energies and how the physico-chemical properties can modulate the energy balance in topological matter.

References
[1] Jongwook Kim *et al.*, *Adv. Funct. Mater.*, **22**, 4949–4956 (2012)
[2] Jeongmo Kim *et al.*, *Nature Commun.* **12**, 1943 (2021)
[3] Jeongmo Kim *et al.*, *Nature Nanotech.* **12**, 914–919 (2017)
[4] Lilian Magermans *et al.*, *In review* (2025)

Shape-Encoded Propulsion: Harnessing Topological Defects in 2D Active Nematic Liquid Crystals

E. Rosas[1*], X. Arqué[1], A. Houston[2], T. Shendruk[3], T. Lopez-León[1]
[1] *Laboratoire Gulliver (UMR 7083), CNRS, ESPCI Paris, PSL Research University, Paris, France;*
[2] *School of Physics and Astronomy, The University of Edinburgh, Edinburgh, UK;*
[3] *School of Mathematics and Statistics, University Place, Glasgow, G12 8QQ, UK.*
[*] *edgardo.rosas@espci.fr*

Active nematics, composed of energy-consuming anisotropic units, exhibit spontaneous flows and topological defects that can drive microscale transport [1]. While defect interactions with static boundaries are well studied [2-3], the use of inclusion shape to control transport of mobile objects remains largely unexplored [3-4]. Here, we show that untethered microstructures immersed in a microtubule–kinesin 2D active nematic can be propelled in a geometry-dependent manner. Using two-photon polymerization, we fabricate inclusions of controlled shapes—circles, ellipses, and crescents—and track the combined motion dynamics of these particles and the surrounding active nematic.

Crescent-shaped inclusions of 150 µm diameter robustly trap +1/2 disclinations in their concavity, leading to persistent propulsion towards the convex side. Propulsion strength increases and rotational motion decreases with crescent polarity, hence, closed shapes show stronger defect entrapment and faster translation. Meanwhile, ellipses exhibit more enhanced rotation for higher aspect ratios, and in all cases less effective translation than crescents. In contrast, circular inclusions of the same diameter show the slowest translational and rotational motion since they lack directional preference.

These results establish a minimal design strategy to convert active nematic flows into directional transport solely based on shape, without requiring anchoring, confinement, or external fields. Our findings introduce a new paradigm for topological guidance of microscale motion, with implications for the design of autonomous, defect-driven soft robotic systems.

References

[1] Doostmohammadi, A., Ignés-Mullol, J., Yeomans, J.M. et al. Active nematics. Nat Commun 9, 3246 (2018).
[2] Hardoüin, J., Hughes, R., Doostmohammadi, A. et al. Reconfigurable flows and defect landscape of confined active nematics. Commun Phys 2, 121 (2019).
[3] Kozhukhov, T., Loewe, B., Thijssen, K. & Shendruk, T. N. Topological kicks enhance colloidal diffusivity in topological turbulence. arXiv (2025)
[4] Vélez-Cerón, I., Guillamat, P., Sagués, F. & Ignés-Mullol, J. Probing active nematics with in situ microfabricated elastic inclusions. Proc. Natl. Acad. Sci. USA 121, e2312494121 (2024).

Acknowledgments

This work was supported by the French National Centre for Scientific Research (CNRS), through a research collaboration between CNRS and the University of Chicago

Optics of liquid crystals:
From passive to active light-matter topological interplay

E. Brasselet
Univ. Bordeaux, CNRS, LOMA, UMR 5798, Talence, France
etienne.brasselet@u-bordeaux.fr

Liquid crystals have long been known for their ability to shape the phase and polarization structure of light — most famously through their use in pixelated devices for liquid crystal displays, and more recently through their role in the topological shaping of light fields, contributing to the emergence of singular optics. Over time, the intrinsic structures of liquid crystals have also become model systems for studying light-matter interactions where the topology of matter is transferred to light [1]. However, this interplay is not unidirectional: light can also shape the topology of liquid crystals.

This talk will explore this duality between passive and active topological coupling in liquid crystal-mediated light-matter systems. On the passive side, liquid crystals act as anisotropic structured media that imprint their geometry onto light. Beyond this passive imprinting lies an active response: the reorientation of the liquid crystal under optical excitation. This active regime was initiated by the 1980 discovery of the optically induced Fréedericksz transition. What began as a simple experimental setup has evolved into a model system for exploring rich nonlinear and topological phenomena, opening new routes toward dynamically tunable topological states in both structured light and soft matter.

References

[1] E. Brasselet, *Singular optics of liquid crystal defects*, Book chapter in Liquid Crystals: New Perspectives, p. 1-79, ISTE Editions and John Wiley and Sons (2021).

Spin-driven optical poling of localized elastic excitations.

Delphine Coursault
Univ. Bordeaux, CNRS, LOMA, UMR 5798, Talence, France
delphine.coursault@u-bordeaux.fr

In cholesteric liquid crystal, localized elastic excitations known as spherulites were discovered in the early 1970s [1]. Their topological diversity was only revealed in 2010 using localized stimulus such as a focused laser beam. However, the morphogenesis of these excitations and their univocal addressability in relation with the nature of the stimuli remain poorly explore. Given that optical effects driven by the spin angular momentum can be used to encode binary information in solids and fluids, we explore the action of circularly polarized light on the orientational thermal fluctuation -that are inherent to liquid crystals- in frustrated cholesteric.

By combining the optical reorientation of liquid crystals with the structural multistability of frustrated chiral liquid crystals, we demonstrate experimentally that the up/down spin state of circularly polarized light can be recorded as an up/down structural state in chiral liquid crystals with high discrimination. This results in a spindriven, nonvolatile, binary liquid crystal memory that can be optically rewritten on demand, opening new avenues for soft memory engineering.

[1] W. E. L. Haas and J. E. Adams, “Electrically variable diffraction in spherulitic liquid crystals,” Appl. Phys.Lett. 25, 263–264 (1974). W. E. Haas and J. E. Adams, “New optical storage mode in liquid crystals,” Appl. Phys. Lett. 25, 535–537 (1974). M. Kawachi, O. Kogure, and Y. Kato, “Bubble domain texture of a liquid crystal,” Jpn. J. Appl. Phys. 13, 1457–1458 (1974).

[2] I. I. Smalyukh, Y. Lansac, N. A. Clark, and R. P. Trivedi, “Three-dimensional structure and multistable optical switching of triple-twisted particle-like excitations in anisotropic fluids,” Nature Mater. 9, 139 (2010).

[3] N. Bruni, C. Loussert, M. Rafayelyan, T. Orlova, D. Coursault, E. Brasselet, Rewritable Binary Recording of the Photon Spin State in Chiral Liquid Crystals, Phys. Rev. Lett. 134, 223804 (2025)

Controlling topological textures of umbilics using spatiotemporal magnetic fields

G. Gonzalez-Cortes[1*], N. Kravets[1], E. Brasselet[1]
[1] Université de Bordeaux, CNRS, Laboratoire Ondes et Matiere d'Aquitaine,
F-33400, Talence, France.
[*] The corresponding author e-mail: gregorio.gonzalez-cortes@u-bordeaux.fr

Liquid crystals are highly sensitive to external fields, particularly electric and magnetic fields [1]. While predicting and controlling the textures induced by external magnets has been a longstanding challenge [2,3], existing solutions often lack flexibility, replicability, or are complex. This work introduces a novel approach for controlling topological defects in liquid crystal layers using spatiotemporally structured magnetic fields. By leveraging the symmetries induced by magnet dynamics, we show how a simple array of four magnets can create reconfigurable textures with umbilics of topological charge ±1 in electrically biased homeotropic nematic liquid crystals. Our experimental findings are validated by comparing the liquid crystal's orientational response to the magnetic torque density from the 3D magnetic field. Additionally, we derive a 2D amplitude equation from the Frank-Oseen free energy, enabling quantitative description and prediction of various liquid crystal topological textures. This method underscores the potential of symmetry-guided field-orientation coupling for defect control, opening new avenues for structuring anisotropic soft materials.

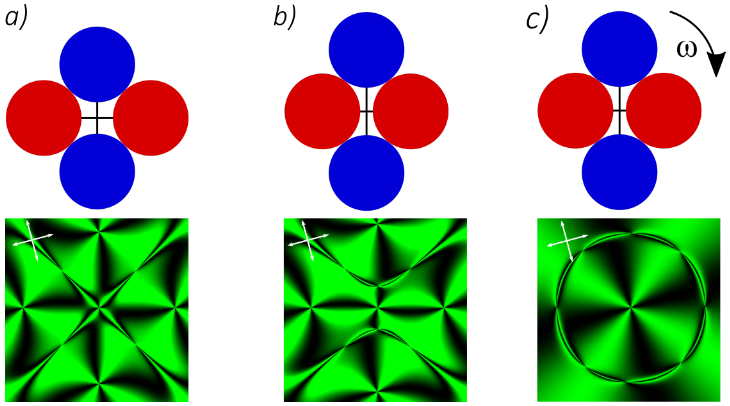


Figure 1: Schematic representation of the effect on liquid crystal textures by the symmetries of magnetic torque on the liquid crystal. Top and bottom row are the magnet configuration and the numerical cross polarized images of simulated textures for the structured magnetic fields. a) Symmetric case: 4 symmetrically positioned magnets generate a +1 central defect. b) Asymmetric case: Central defect has a -1 topological charge. c) Restored symmetry by magnet rotation results in a +1 central defect.

References
[1] P. Oswald, & P. Pieranski, *Smectic and columnar liquid crystals: concepts and physical properties illustrated by experiments*,CRC press (2005)
[2] T. Frisch, S. Rica, P. Coullet, J. M. Gilli, *Physical review letters*, **72(10)**, 1471 (1994)
[3] P. Pieranski, B. Yang, L. J. Burtz, A. Camu, F. Simonetti, *Liquid Crystals*, **40(12)**, 1593-1608 (2014)

Acknowledgments
This research was partially financed by French National Research Agency (ANR) as part of the project ANR-23-CE06-0013-01. GGC thanks for the European Union's Horizon research and innovation program Marie Sklodowska-Curie grant OPS-CLC agreement No 101027737.

Revisiting the annihilation dynamics of umbilics in nematics

K. Joshi, G. Gonzalez-Cortes, E. Brasselet, and N. Kravets
LOMA – CNRS UMR5798, Talence, France
[*] *The corresponding author e-mail: kamlesh.joshi@u-bordeaux.fr*

Liquid crystals (LCs) exhibit a rich variety of orientational structures and topological defects due to their anisotropic molecular arrangement, which can be manipulated via external electric, magnetic, or optical fields. Among the various types of defects, umbilics are well-known and long-studied example, playing an important role in our understanding of topological defects in liquid crystals. Umbilics are localized topological defects emerging under the influence of an electric field applied to a slab of nematic liquid crystal with negative dielectric anisotropy provided with homeotropic alignment [1].

In this study, we experimentally revisit the annihilation dynamics of 2D distributions of umbilics in the proximity of the electric Fréedericksz transition. The Fréedericksz threshold voltage (V_F) [2] is defined as the minimum electric potential difference between the electrodes of the LC sample at which reorientation of the liquid crystal director begins. To access the quantitative parameters of annihilation dynamics, we estimate the number of defects at each time using polarization microscopy [3] (see Fig.1). This enables the quantitative tracking of annihilation dynamics. In contrast to what is reported in literature for voltages far stronger than V_F [4,5], we observe the variation of exponential decay coefficient, for which no explanation is currently available in the literature. In my presentation, I will discuss possible interpretation of the observed trend using a power-law decay function with fitted parameters describing the effective starting time of annihilation and residual unannihilated defects.

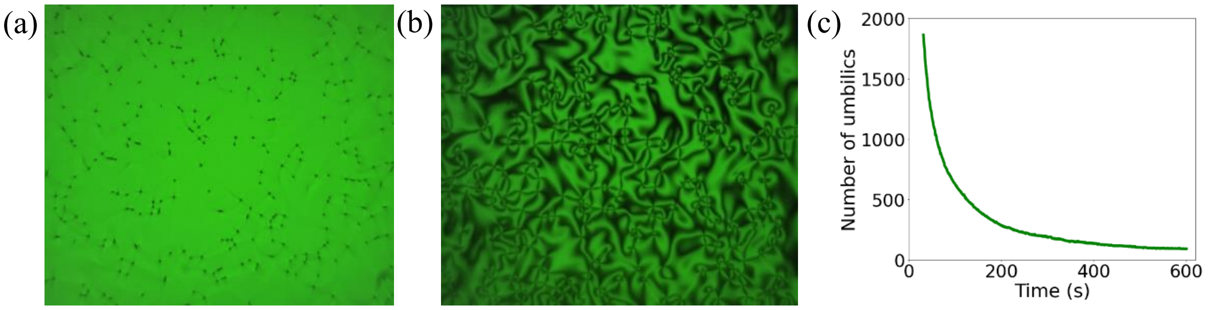


Fig.1 Snapshots of umbilics 2 min after the start of annihilation process at a voltage 12% higher than V_F taken in between (a) crossed circular polarizers, and (b) crossed linear polarizers. (c) Corresponding temporal evolution of the number of umbilics in the field of view.

References

[1] A. Rapini. *Journal de Physique* **34**, 629-633 (1973).
[2] P. Oswald, and P. Pieranski. *Two Volume Set. Crc Press*, (2018).
[3] T. Scharf. *John Wiley & Sons,* (2006).
[4] I. Dierking, O. Marshall, J. Wright, and N. Bulleid. *Physical Review E* **71**, 061709 (2005).
[5] V. Zambra, M. G. Clerc, R. Barboza, U. Bortolozzo, and S. Residori. *Physical Review E* **101**, 062704 (2020).

Acknowledgments

This work is supported by the ANR EDISONe (ANR-23-CE06-0013-01).

Liquid crystal particle-like structure driven by light

Emma Furlanetto[1,*], Delphine Coursault[1] & Etienne Brasselet[1]
1) LOMA, CNRS, University of Bordeaux, Talence, France
** Contact : emma.furlanetto@u-bordeaux.fr*

Optical trapping is a well-known phenomenon in the case of solid objects, where the center of mass—the positional degrees of freedom—can be manipulated. In liquid crystals, which belong to the family of ordered fluids, one usually deals with orientational rather than positional degrees of freedom. Here we report on the optical manipulation of particle-like orientational structures existing in liquid crystals endowed with intrinsic helical orientational order. These structures are elastic in nature and it is known that they can be manipulate under the action of light, making such elastic particle-like structures to move on demand.

In this work we unveil a surprising optical manipulation phenomenon of elastic particle-like structures, namely, a polarization-controlled optomechanical push-pull effect, Fig.1(up). Liquid crystals being birefringent materials, one expects that their manipulation depends on the polarization state of light, however, our unpredicted observations raise new questions. Indeed, we demonstrate that the effect is generic, being neither nonspecific to a given material, sample preparation, nor to light-matter interaction geometry. Therefore, what drives such a behavior ?

In order to elucidate the process of light-matter interaction at work, we have explored two avenues. The first option is to consider that elastic particle-like structures behave as a rigid-body optically anisotropic scatterers subject to radiation pressure effects. In fact, for solid objects, it is known that polarization-dependent push-pull effects can occur in bespoke situations. The second option is to take into account of light-induced changes of the internal orientational order of elastic particle-like structures, a process that is expected to depend on polarization. So far, our experimental investigations, supported by modelling, tend to confirm that the latter option is at work, Fig.1(down).

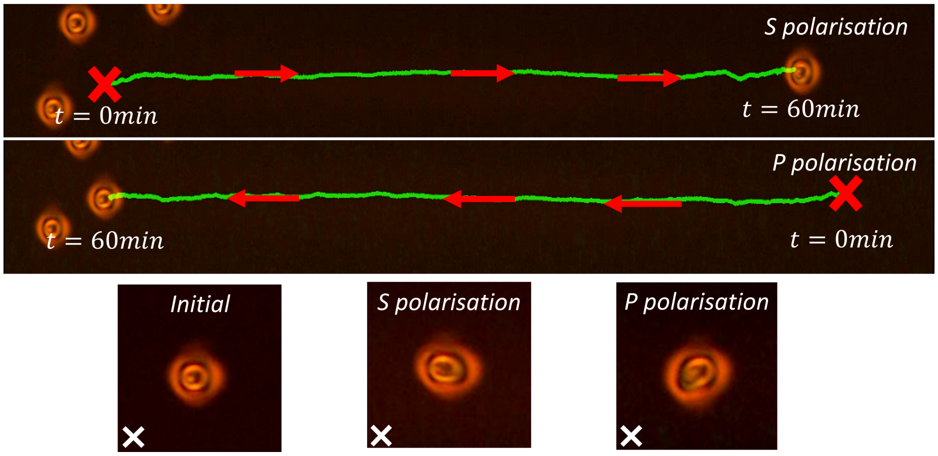


FIGURE 1 – (up) Evolution of particle-like structures positions over time for two incident laser polarizations. Red arrow refers to direction of displacement. (down) Deformation of particle-like structures in case of high power laser for both polarization.

Tunable optical skyrmions from liquid crystal droplets

Mufeeduzaman Chavilkkadan[1*], Etienne Brasselet[1]
[1] *Univ. Bordeaux, CNRS, LOMA, UMR 5798, Talence, France*
[*] *The corresponding author e-mail: mufeeduzaman.chavilkkadan@u-bordeaux.fr*

Recent advances in research have extended the concept of skyrmions—topologically stable vector textures originally introduced in particle physics—to various fields, including electromagnetism and optics [1]. In photonics, skyrmions have shown immense potential, particularly in driving innovation in advanced beam-shaping strategies. Liquid crystal spatial light modulators have emerged as promising platforms for the generation and manipulation of optical skyrmions due to their tunable optical properties. However, these devices are often bulky and expensive, prompting the exploration of alternative systems. In this study, we exploit the spin-orbit interaction of light and the tunable birefringence of liquid crystals under external fields [2] to experimentally achieve the controlled generation of optical skyrmions using liquid crystal droplets.

Here we exploit the unique ability of nematic liquid crystal droplets to modulate optical anisotropy through the self-organisation of the long-range orientational order of liquid crystals. Specifically, we have arranged the orientational boundary conditions in order to obtain spatial modulation of both the optical axis orientation and the birefringent phase retardation between ordinary and extraordinary waves passing that propagate through the droplet. This enables the transformation of a uniformly polarised input beam into skyrmionic polarization textures.

We experimentally demonstrate the production of first-order skyrmion structures at an arbitrary wavelength in the whole visible domain by varying the droplet radii over a couple of hundreds of micrometres. Moreover, we have developed a model that does not only provides an accurate description of the observation but also allows precise prediction of the generation of high-order skyrmions by appropriately selecting the droplet geometrical and optical characteristics.

This opens up avenues for tailoring skyrmion configurations on demand. Specifically, we take control of the properties of the generated skyrmions by applying external thermal and electrical fields to the liquid crystal system. In turn, the operating wavelength for a given skyrmion can be tuned on demand. Moreover, the nature of the skyrmion can be changed at a given wavelength. All the observations are supported by our modelling.

This work not only broadens the understanding of skyrmion behaviour in liquid crystal systems but also provides a versatile platform for applications in advanced optical technologies.

References

[1] Y.Shen, Q.Zhang, P.Shi, et al. *Nature Photon*, **18-1**, 15-258 (2024)
[2] B. Etienne, *Physical Review Letters***, 103**, 103903(2009)

Acknowledgments

This work has been done under the financial support from the French National Research Agency (ANR-21-CE24-0014-01) and IdEx University of Bordeaux and its Grand Research Program GPR LIGHT.

Nanoparticles and liquid crystal defects

Emmanuelle Lacaze
[1] *Institut des NanoSciences de Paris, CNRS, Sorbonne Université, Paris, France*
[*] *The corresponding author e-mail: emmanuelle.lacaze@insp.jussieu.fr*

The study of composites liquid crystal/nanoparticles starts to be a mature thematics in the field of liquid crystal research. In this talk I will try to emphasize the difficulties associated with these composites, what could be seen as part of the most promising future associated with these composites and how, using advanced experiments in particular performed with synchrotron facilities, we now make significant progresses in the understanding of these composites.

I will in particular focus on composites that are formed in presence of liquid crystal topological defects. Indeed nanoparticles get easily trapped inside defect cores, allowing for nanoparticle confinement into specific localizations and allowing for nanoparticle assemblies templated by the defect geometry. Through different kinds of experimental X-ray diffraction studies, I will show that it is now possible to define highly distorted smectic films with three kinds of coexisting topological defects, disclinations, dislocations and topological grain boundaries [1, 2, 3].

By varying size, shape and concentration of nanoparticles, I will show how to precisely study the interactions between nanoparticle and defects responsible for the observed nanoparticle organization within the defects [4, 5]. We are now able to precisely select the defect nature between the three possible ones for the confinement of nanoparticles. Depending on the defects, the nanoparticle assemblies are different but always of controlled orientation. This finally leads to modulated optical properties of the nanoparticles, controlled by light polarization [4, 5] but also by the temperature when we take advantage of the liquid crystal phase transition to create or annihilate the defects [6].

References

[1] B. Zappone and E. Lacaze, *Liquid Crystal Review* (2022)
[2] J. de D. Niyonzima et al, *Phys Rev Lett.*, **124**, 018101 (2025)
[3] L. Musarec et al., *Surf. And Interf.*, **63**, 106294 (2025)
[4] S.P. Do et al., *Nano Lett.* **20** 1598 (2020)
[5] H. Jeridi et al., *Soft Matt.* **18** 4792 (2022)
[6] H. Jeridi et al., *Appl. Phys. Lett.***123** 203101(2023)

Structure and dynamics of 2D-ribbons in liquid crystal topological defects

*L. Essaoui[1],J. Niyonzima[1], C.Tosarelli[1], C.Abadie[1],H.Jeridi[1,2], A.Vlad[3], A.Coati[3], Y.Prado[1] S.Royer[1], D.Constantin[4], M. Goldmann[1,3], Y. Garreau[3,5], D.Babonneau[6], I.Trimaille[1] B.Croset[1], E. Lhuillier[1], E. Lacaze[1]
*Corresponding author: essaoui@insp.jussieu.fr

[1]*Sorbonne Université, CNRS, Institut des Nano-Sciences de Paris (INSP), F-75005 Paris, France ;* [2]*OMNES Education Research Center, ECE Paris, 37 Quai de Grenelle, 75015 Paris, France ;* [3]*Synchrotron SOLEIL, BP 48, L'Orme des Merisiers, 91192 Gif sur Yvette Cedex, France ;* [4]*Université de Strasbourg, Institut Charles Sadron, CNRS UPR022, 67034 Strasbourg Cedex, France ;* [5]*Université Paris Cité, Laboratoire Matériaux et Phénomènes Quantiques, CNRS, F-75013 Paris, France ;* [6]*Département Physique et Mécanique des Matériaux, Institut P', UPR 3346 CNRS, Université de Poitiers SP2MI, TSA 41123, 86073 Poitiers cedex 9, France*

Keywords: liquid crystals, nanoparticles, self-assembled, diffusion, instability

Smectic liquid crystals (LCs) host a variety of topological defects (TDs) [1] where nanoparticles can be confined and organized [2,3]. We have shown that the confinement induced by smectic patterns made of assemblies of oriented ribbon-like grain boundaries (2-dimensional topological defects) leads to the formation of aligned ribbons of fluorescent nanorods [4].

We study the dynamics of these nanorod assemblies in relation to their confinement within smectic TDs. It has been shown previously that in LC matrices, particle dynamics often departs from Brownian-like diffusion [5,6]. Our study aims at better understanding the confinement-induced dynamics within smectic TDs. This is motivated by two key aspects: first, structural information on the defect matrix may be inferred indirectly from the dynamics; second, the dynamics itself may actively reshape the structure of the nanorod assemblies, and thus requires precise control.

We combine optical microscopy, fluorescence microscopy, and synchrotron-based grazing incidence X-ray scattering (GISAXS) to investigate the structure and dynamics of the assemblies. A unidirectional motion is observed along the defects, reflecting the strict confinement of the nanorods within the oriented ribbon-like smectic defects. This motion features two regimes: small-scale fluctuations (up to 50 nm) and intermittent jumps between two stable positions separated by approximately 200 nm. This behavior is reminiscent of sub-diffusive dynamics observed for particles confined in polymer networks, where the mesh size is comparable to the particle diameter [7]. It reveals that the motion of nanorod assemblies in smectic TDs is trap-like. Furthermore, the amplitude of the fluctuations depends on the size of the nanorod assemblies, confirming that smectic elasticity—induced by the trapping of nanorods larger than the defect core—generates a confining, multi-well potential landscape. This multi-well potential landscape leads to an activated dynamics that can be interpreted within the framework of continuous-time random walks (CTRW), commonly used to describe heterogeneous or glassy transport processes[8]. This approach opens new perspectives for understanding how topological confinement in soft anisotropic matrices governs both structural organization and non-Brownian dynamics at the nanoscale.

References:

[1] B. Zappone et E. Lacaze, *Liq. Cryst. Rev*, 1-18, (2022)
[2] S.P. Do et al., *Nano Lett.* 1598-1606, (2020) [3] D. Coursault et al., *Soft Matter*, **12**, 678-688 (2016)
[4] H. Jeridi et al., *Soft Matter* **18,** , 4792-4802, (2022)
[5] K. May, Kathrin et al., *J. Mol. Liq.* 267,322-29, (2018)
[6] E. Grelet et al, *Phys. Rev. Lett*. **99**, 197802 (2007)
[7] I. Y. Wong et al., *Phys. Rev. Lett.* **92**, 178101 (2004).
[8] F. Höfling et al, *Reports on Progress in Physics*, **76**, 046602 (2013)

Shape of topological defects — and consequent motion — in active nematics

G. M. La Montagna[1*], S. Burekovič[2,3], A. Maitra[1,4], C. Nardini[2,3]
[1] Laboratoire de Physique Théorique et Modélisation, CNRS UMR 8089, CY Cergy Paris Université, F-95032 Cergy-Pontoise Cedex, France; [2] Service de Physique de l'Etat Condensé, CEA, CNRS Université Paris-Saclay, CEA-Saclay, 91191 Gif-sur-Yvette, France; [3] Sorbonne Université, CNRS, Laboratoire de Physique Théorique de la Matière Condensée, 75005 Paris, France; [4]Laboratoire Jean Perrin, Sorbonne Université and CNRS, F-75005, Paris, France
[*] The corresponding author e-mail: giacomomarcolamontagna98@gmail.com

Topological defects in systems with liquid-crystalline order are crucial in determining their large-scale properties. In active systems, they are known to have properties impossible at equilibrium: for example, +1/2 defects in nematically-ordered systems self-propel. While some previous theoretical descriptions relied on assuming that the defect shape remains unperturbed by activity, we show that this assumption can lead to inconsistent predictions. We compute the shape of −1/2 defects and show that the one of +1/2 is intimately related to their self-propulsion speed. Our analytical predictions are corroborated via numerical simulations of a generic active nematic theory.

References

[1] G. M. La Montagna, S. Burekovič, A. Maitra, C. Nardini, *arXiv*, 2504.19665 (2025)

Acknowledgments

AM and CN acknowledge the support of the ANR grant PSAM. CN acknowledges the support of the INPIRP grant IFAM and from the Simons Foundation. SB, AM and CN thank the Isaac Newton Institute for Mathematical Sciences for support and hospitality during the program "Anti-diffusive dynamics: from sub-cellular to astrophysical scales" during which a part of this work was undertaken. AM acknowledges a TALENT fellowship awarded by CY Cergy Paris Université

Interaction between real and optoelastic colloids in nematic liquid crystals

Malackoth Muhammed Rasi,[1] Nina Kravets[1], Delphine Coursault[1] and Etienne Brasselet[1]
[1] University of Bordeaux, CNRS, Laboratoire Ondes et Matière d'Aquitaine (LOMA),
F-33400 Talence, France.

muhammed-rasi.malackoth@u-bordeaux.fr

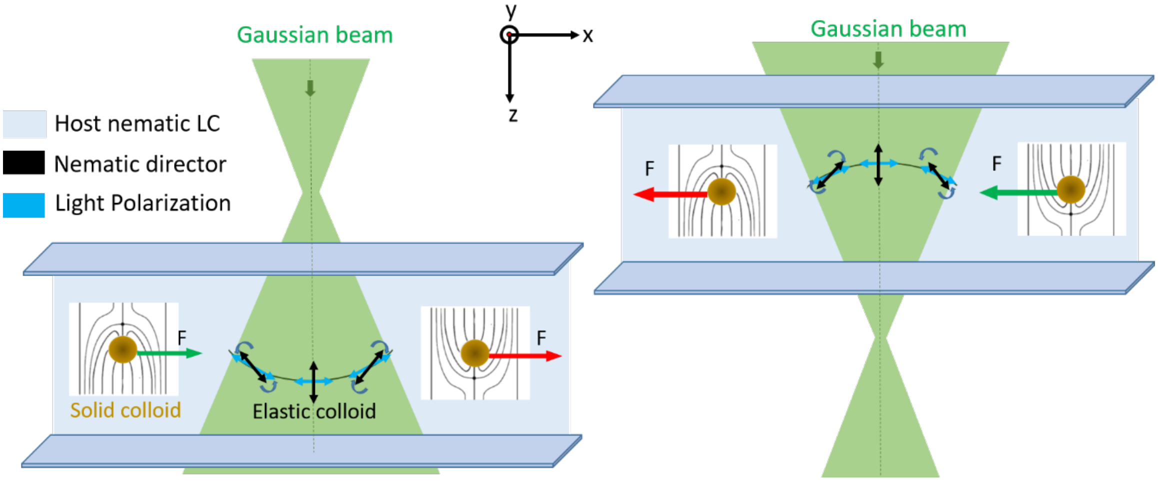


Fig.1: Experimental sketch. A solid colloid with a dipolar point defect in nematic fluid interacts with a laser-induced optocolloid, experiencing an attractive (green arrow) or repulsive (red arrow) optoelastic force *F* depending on the defect position and beam divergence.

Colloidal dispersions in liquid crystals are extensively used in a wide range of both fundamental and applied research. Among the factors sustaining interest in this topic are their distinctive and highly tunable interactions, governed by the anisotropic properties of the host nematic medium. In particular, the large variety of long-range interactions through the elastic distortions in the nematic director field is assured by topological defects in director field around colloids. Beyond solid colloid inclusions, an intriguing research avenue focuses on light-induced colloid-like structures in liquid crystals. These local nematic director reorientations can be on-demand created through optical forces exerted by properly tailored laser beams. Provided that both conventional solid colloids and light-induced elastic "colloids" are associated with director distortion, they interact between each other [1, 2]. Such interaction can potentially be guided by the exact geometry of director distortion. It has been reported that complex 3D director field can be generated when the longitudinal field component of light is at work [3]. This suggests that elastic "colloids" endowed with on-demand elastic multipolar structures could be generated. Here, we experimentally demonstrate a proof of principle by generating a dipolar elastic "colloid" whose up or down polar nature can be directly assessed by studying attractive/repulsive force F exerted on a neighboring solid colloid, as shown in Figure 1. The case of dipolar elastic "colloid" written by circularly polarized Gaussian beam can be extended to more complex multipole cases by modifying Gaussian beam polarization state as well as employing a variety of structured light beams such as scalar or vectorial optical vortex beams.

References

[1] I. Musevic et al., *Phys. Rev. Lett.* **93**, 187801 (2004).
[2] L. Criante et al., *Soft Matter.* **9**, 5459 (2013).
[3] M. El Ketara, H. Kobayashi ,and E. Brasselet, *Nature Photonics.* **15**, 121-124 (2021).

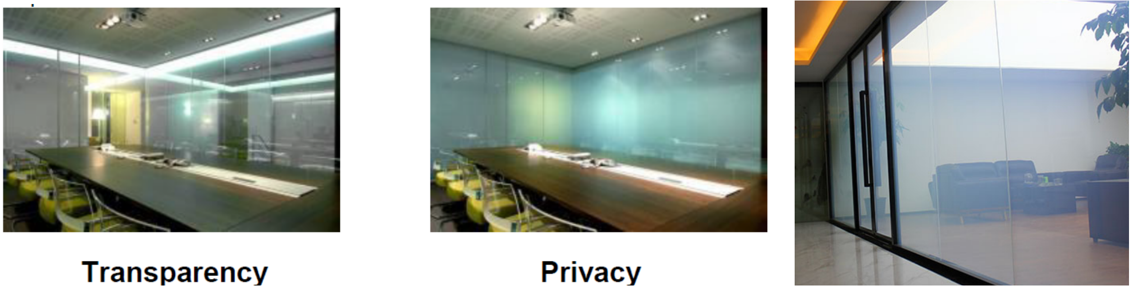
Acknowledgments

This work was supported by the GPR light (project No: **ANR-23-CE06-0013-01**).

Liquid crystal-based active glazings for Saint-Gobain

A. Fouques[1*]
[1] *Saint-Gobain Recherche Paris, 41 quai Lucien Lefranc 93300 Aubervilliers*
[*] *The corresponding author e-mail: axel.fouques@saint-gobain.com*

Active glazings offer an additional function that users can trigger on-demand: tint, opacity, display, heating etc. This function may be brought by thin films deposited on glass, or through a liquid crystal-based (LC-based) device embedded in the glazing. In the LC-based active glazings on the market Privalite®, Amplisky® and Solarbay®, the function is provided by a polymer-dispersed liquid crystal (PDLC) technology. PDLC is a mature technology for the building market segment, whereas it has only been introduced recently in the automotive market segment. It has been quickly adopted in car roofs so that mass market penetration is expected in the coming couple of years.



Transparency **Privacy**

Figure 1 : (Left) Visual appearance of a privacy active glazing in the transparent and scattering mode. (Right) Residual haze in angle in the transparent state.

This presentation will introduce the principle of the PDLC technology along with its main drawbacks, namely the cost of the film and the residual haze in angle. The presentation will then go into the different R&D developments aiming at solving issues in the PDLC product or improving the active glazing function. A no-polymer privacy solution based on electrohydrodynamic instabilities generated by ions will be introduced, for which the main challenge is its integration into a glazing without defects following the lamination process.

Figure 2: Visual appearance of a guest-host liquid crystal sidelite prototype in transparent and tinted state.

Dye-doped PDLC (DD-PDLC) and guest-host liquid crystals (GHLC) tintable active glazing technologies will also be presented along with the main integration challenges they raise, namely lamination without defects and dye durability against light and heat exposure. The presentation will eventually open to promising LC-based building blocks that can be incorporated in these technologies to provide additional functions [1, 2].

References

[1] C.-C. Li, H.-Y. Tseng, T.-W. Pai, Y.-C. Wu, W.-H. Hsu, H.-C. Jau, C.-W. Chen, T.-H. Lin, *Applied Optics*, **53**, E33-E37 (2014)
[2] A. Moheghi, H. Nemati, Y. Li, Q. Li, D.-K. Yang, *Optical materials*, **52**, 219-223 (2016)

Liquid Crystal-Based Polymer Nanocomposites for Energy Storage and Conversion

Jinkai Yuan
Sorbonne Université, CNRS, Chimie de la Matière Condensée de Paris, LCMCP, F-75005 Paris, France
* *The corresponding author e-mail: jinkai.yuan@sorbonne-universite.fr*

In this presentation, I will talk about our research activities over the past years on polymer composites based on liquid crystalline 2D materials. The self-assembly of nanosheets into liquid crystalline structures within a polymer matrix allows the creation of new composite structures, affording promising dielectric properties that are highly demanded for the design of electrostrictors and energy storage capacitors. I will first show a giant electrostriction effect in liquid crystalline graphene-doped soft elastomers. Because of the locally aligned structure within nematic domains, the achieved percolative network differs greatly from those obtained by randomly mixed composite systems, resulting in a giant permittivity and ultralarge electrostriction coefficient. To go further, we combined liquid crystal inks with Direct Ink Writing. The aim is to exploit the shear-induced alignment of the nematic phases during 3D printing to achieve multiple structural control over length scales from nano to macroscopic. Such a 3D ordered composite structure is desirable for the development of high-energy dielectric capacitors.

References

[1] J. Yuan, et al, Nat. Commun. 2015, 6, 8700.

[2] J. Yuan, et al. ACS Nano 2018, 12, 1688-1695

[3] Nessera, H. et al, Nano Energy, 2018, 44, 1–6.

[4] M. Bronchy, et al, under preparation, 2025

Acknowledgments
This work was supported by the ANR ElENA, DIM MaTerRE LIPSEC.

FROM RESIDUAL MESOGENS TO RESPONSIVE MATERIALS: RECYCLED LIQUID CRYSTALS FROM ENDOF-LIFE SCREENS IN PHOTOCURABLE ACRYLATE NETWORKS

A. Bouriche [1,2*], A. Barrera[2] , C. Binet[2] , P. Ropa[3] , F. Dubois[3] , L. Alachaher-Bedjaoui[1] ,
Z. Bouberka[4] and U. Maschke[2]

[1] Laboratoire de Recherche sur les Macromolécules (LRM), Faculté des Sciences, Université Abou-bekr Belkaïd de Tlemcen (UABT), BP 119, 13000 Tlemcen, Algeria,
[2] Unité Matériaux et Transformations (UMET), UMR 8207, Université de Lille, CNRS, INRAE, Centrale Lille, F-59000 Lille, France,
[3] Unité de Dynamique et Structure des Matériaux Moléculaires (UDSMM), UR 4476, Université du Littoral – Côte d'Opale, CS 80699, 62228 Calais, France,
[4] Laboratoire Physico-Chimie des Matériaux-Catalyse et Environnement (LPCMCE), Université des Sciences et de la Technologie d'Oran Mohamed Boudiaf (USTOMB), BP 1505, El M'naouer, Oran 31000, Algeria,

[*] The corresponding author e-mail: a_bouriche@yahoo.fr

Photocurable composites were developed using isobornyl acrylate and recycled liquid crystal components, cured under ultraviolet light with a reactive crosslinker and photoinitiator. Physical characterization included infrared spectroscopy, differential scanning calorimetry, dynamic mechanical analysis, and rheology. Spectroscopy confirmed over 90% conversion of carbon–carbon double bonds. Calorimetry revealed suppression of mesophase transitions, indicating effective encapsulation. Mechanical analysis showed a glass transition temperature decrease from approximately 90°C to 65°C and a marked reduction in stiffness. Rheological measurements indicated enhanced flow due to lower viscosity. These results demonstrate a plasticizing effect and compatibility of the recycled liquid crystals, enabling tunable functional properties for optical applications.

Keywords: Photopolymerization; glass transition; mesophase; storage modulus

References

[1] J. Cui, N. Zhu, Y. Li, D. Luo, P. Wu, Z. Dang, Rapid and green process for valuable materials recovery from waste liquid crystal displays, Resources, Conservation and Recycling, **153**, 104544(2020)

[2] A. Barrera, C. Binet, F. Danede, J.F. Tahon, B. Ouddane, F. Dubois, P. Supiot, C. Foissac, U. Maschke, Chemical Characterization and Thermal Analysis of Recovered Liquid Crystals, *Crystals,* **13** , 1064 (2023)

[3] S. Agarwal, S. Srivastava, S. Joshi, S. Tripathi, B. Pratap Singh, K. Kumar Pandey, R. Manohar, A Comprehensive Review on Polymer-Dispersed Liquid Crystals: Mechanisms, Materials, and Applications, *ACS Materials Au*, **5**, 88-114 (2025)

Structural color in assemblies of colloidal particles: from liquid crystalline suspensions to structured solid materials

B. Frka-Petesic[1,2*]
[1] *Yusuf Hamied Department of Chemistry, University of Cambridge, Cambridge, UK*
[2] *International Institute for Sustainability with Knotted Chiral Meta Matter (WPI-SKCM^2),*
Hiroshima University, Hiroshima 739-8526, Japan;
[*] *The corresponding author e-mail: bf284@cam.ac.uk*

Structural color emerges from a variety of ordered structures at the submicron scale instead of relying on chemical-specific spectral absorption. A simple way to produce structurally colored materials is to rely on the self-assembly of colloidally stable Cellulose Nanocrystals (CNCs), which are anisotropic and chiral colloidal nanorods extracted from cellulose biosources. These CNCs are able to spontaneously self-assemble into a cholesteric phase above a critical concentration, which can be retained in the solid state upon drying and reflects specific wavelengths in the visible range.[1-2]

In this talk, I will review the key factors to control the self-assembly of these CNCs in suspension, and highlight the essential role of geometry and time scales. In particular, I will discuss the effect of drying conditions onto a substrate or in emulsion, the effect of good wetting vs non-wetting conditions, fast and slow evaporation times and the effect of buckling.[3-4]

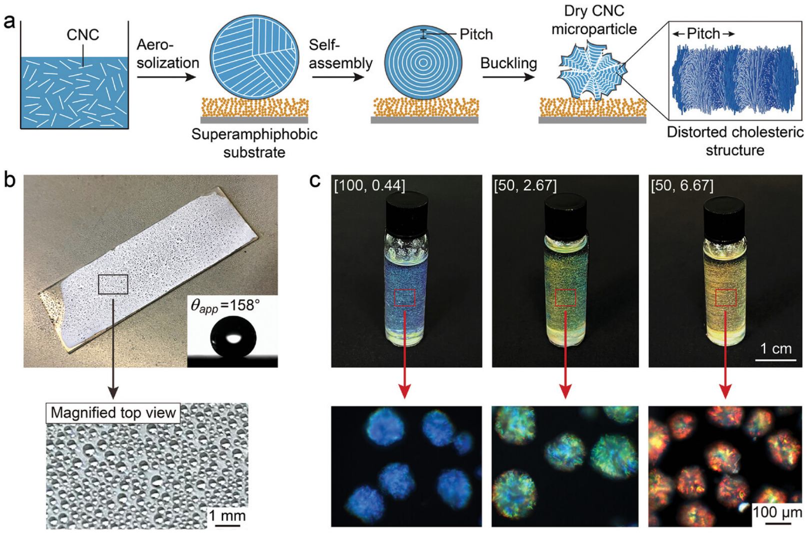


Figure 1. Structurally colored pigments made from CNC buckled particles. a) schematic of their assembly, b) deposition of the suspension, c) final particles made from suspensions formulated as [*NaCl/CNC ratio* (µmol/g), *sonication dose* (s/mL)] (reproduced from [4], CC BY 4.0).

References

[1] R. M. Parker, G. Guidetti, C. A. Williams, T. Zhao, A. Narkevicius, S. Vignolini, B. Frka-Petesic, *Adv. Mater.* **30**, 1704477 (2018)
[2] B. Frka-Petesic, G. Kamita, G. Guidetti, S. Vignolini, *Phys. Rev. Mater.*, **3**, 045601 (2019)
[3] R. M. Parker, T. H. Zhao, B. Frka-Petesic, S. Vignolini, *Nat. Commun.* **13**, 3378 (2022)
[4] J. Song, R. M. Parker, B. Frka-Petesic, T. Deng, L. Xu, X. Deng, S. Vignolini, Q. Shen, *Adv. Mater.* **37**, 2416607 (2025)

Acknowledgments

This work was supported by the EPSRC (project No. EP/W031019/1), ERC Horizon 2022 Proof of Concept Grants (project No. 101082172), and Hiroshima University (WPI-SKCM^2).

ZnO nanopillars and liquid crystals for hybrid solar cells

KHOL Bator[1], MATHIEU Christian[1], SAITZEK Sébastien[1], BLACH Jean-François[1]

[1] Unité de catalyse et chimie du solide (UCCS), UMR 8181 CNRS Université d'Artois, Faculté des sciences Jean Perrin, 62300 Lens, France

email: bator.khol@univ-artois.fr

Keywords: Hybrid solar cells; Liquid crystals; Nano-pillars; P/N Heterojunctions; Electrodeposition

Abstract :

With the ever-increasing global population and the resulting energy demand, it is crucial to develop renewable energy sources to replace fossil fuels. In this context, our research focuses on designing a simple and cost-effective alternative to current silicon-based solar cells, which also have relatively polluting chemistry.

Our research aligns with this approach by exploring a simple, economical, and more environmentally friendly alternative to conventional silicon-based photovoltaic cells, whose production remains energy-intensive and chemically polluting. We propose the development of hybrid solar cells based on P/N heterojunctions utilizing liquid crystal semiconductor materials (1-benzothieno[3,2-b][1]benzothiophene [2,3]: Ph-BTBT-10) and zinc oxide (ZnO) nanopillars.

This liquid crystal is chosen due to its excellent charge carrier mobility (μ=13 $cm^2V^{-1}S^{-1}$) and the molecular order found in these materials. This order favors efficient charge carrier transport across the layer thickness, leading to improved efficiencies when integrated into photovoltaic devices [2].

In this work, we present the synthesis of ZnO nanopillars and the control of their growth using the electrodeposition technique on various substrates with zinc acetate and nitrate precursors, followed by the deposition of Ph-BTBT-10 liquid crystal molecules onto the ZnO nanopillars. The characterization of the ZnO nanopillars is performed using X-ray diffraction (XRD) and scanning electron microscopy (SEM). These analyses demonstrate the specific growth of nanopillars with strong anisotropy, which can be described by the c-axis perpendicular to the substrate plane. We also determined the photoluminescence properties of the synthesized samples to evaluate the presence of oxygen vacancies. We will show that this is related to the photo-electrical behavior of the samples. Finally, the electrical characteristics of the metal/semiconductor (ZnO and Ph-BTBT-10) interfaces, as well as the current-voltage curve of the complete solar cell under illumination using a solar simulator, are presented and discussed.

References

[1] S. Sanchez, "Fabrication of Nanostructured Solar Cells Based on ZnO Nanowires", PhD thesis, Université de Grenoble, 2012.

[2] H. Iino, T. Usui, and J.-I. Hanna, "Liquid crystals for organic thin-film transistors", Nature communications, vol. 6, p. 6828, Apr. 2015, DOI: 10.1038/ncomms7828

[3] M. Dhennin, "Films minces organiques auto-organisés et dopés en nanoparticules pour des applications photovoltaïques", Master, UCCS, Faculté Jean Perrin Lens, 2022.

[4] E. Niemec, "Durability of a Nanostructured Zinc Oxide Coating Developed by Soft Chemistry for Antibacterial and Self-cleaning Surfaces", PhD thesis, Université polytechnique Hauts-de-France et l'INSA Hauts-de-France, 2021.

Semiconducting polymer-based alignment layers for liquid crystal modulators.

T. Ducatel*, Y. Lin, T. Heiser
Laboratoire des sciences de l'ingénieur, de l'informatique et de l'imagerie (UMR 7357),
Université de Strasbourg, 23 rue du Lœss, 67037 Strasbourg, Cedex 2 France.
* *thomas.ducatel@etu.unistra.fr*

Ionic impurities in thermotropic liquid crystal (LC) materials are unavoidable and contribute to operation instabilities of spatial light modulators. An inconvenient electric field may cause these ions to drift towards device's alignment layers (AL) and impose a voltage drop at AL/LC interfaces, leading to optical artefacts like image sticking or flickering [1]. Such issues force LC devices to be operated under high frequency (> kHz) alternative electric fields and the use of LC materials with low ionic conductivities ($< 10^{-12}\ \Omega^{-1}.m^{-1}$). Though, this can be challenging to satisfy for applications where power consumption and/or threshold voltage are key parameters to minimize.

These considerations are critical for Photovoltaic Spatial Light Modulators (PSLMs) devices (Figure (a)). PSLMs form a new class of self-powered optically addressed modulators able to control the LC birefringence through a photovoltaic effect [2]. Under illumination, the photovoltaic component acts as a continuous generator (DC) and could expose PSLMs to ionic impurities related effects. However, the influence of impurities in PSLMs is attenuated, since the birefringence of a high dielectric anisotropy LC material ($\Delta\varepsilon = 44.5$ at 1kHz) can be maintained for 5 hours under 100 mW/cm² light (Figure (b)) [2]. This DC voltage operation is possible thanks to non-classical polymer AL materials, i.e., semiconducting polymers.

In this work, we first detail the positive influence of this new AL material on the DC voltage operation of a light valve, which will be compared to classical AL material (Figure (c)) [3]. The underlying mechanism of this ion management will be finely described. Finally, the opportunities offered by these new types of alignments layers for liquid crystals modulators will be discussed.

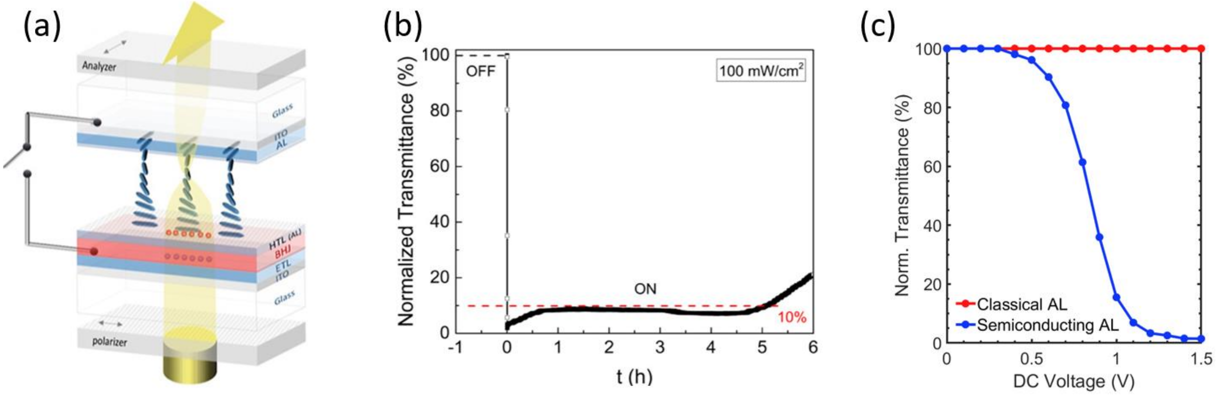


Figure - (a) PSLM structure in OFF state and (b) PSLM transmittance under 100 mW/cm² AM 1.5G spectrum over time [2]. (c) DC voltage dependance of twisted nematic cells transmittance with different AL materials.

References
[1] Y. Garbovskiy, *Liquid Crystals Reviews*, **13**, 1–57 (2025)
[2] S. Fall et al, *ACS Appl. Mater. Interfaces*, **15**, 4267–4274 (2023).
[3] T. Ducatel et al, *Liquid Crystals Optics and Photonic Devices*, 13016, 114–119 (2024)

POSTERS LIST

Topological metadefects: tangles of dislocations

P. Pieranski[1], M. Zeghal[1] and P. Judeinstein[2], M. H. Godinho[3]
R. Bouffet-Klein[4], B. Liagre[4], N. Rouger[4]

[1] *Laboratoire de Physique des Solides, Université Paris Saclay, Orsay, France*
[2] *Université Paris-Saclay, CEA, CNRS, LLB, 91191 Gif-sur-Yvette, France*
[3] *i3N/CENIMAT, NOVA University Lisbon, Portugal*
[4] *ENS Paris-Saclay, 4 Avenue des Sciences, 91190 Gif-sur-Yvette, France*

The concept of topological defects is universal. In condensed matter, it applies to disclinations, dislocations, or vortices that are fingerprints of symmetry breaking during phase transitions.

Using as a generic example the tangles of dislocations, we introduce the concept of topological metadefects, i.e., defects made of defects. We show that in cholesterics, dextrogyre and levogyre primary tangles are generated through the D2 → C2 symmetry breaking from the coplanar dislocation pair called Lehmann cluster submitted to a high enough tensile strain.

The primary tangles can be wound up individually into double helices. They can also annihilate in pairs or associate into tangles of higher orders following simple algebraic rules.

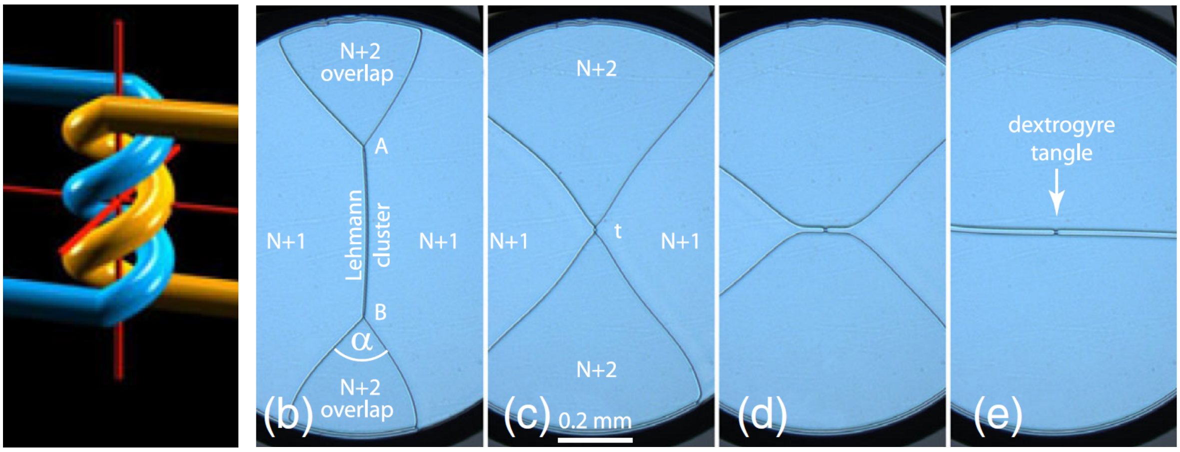


Figure 1: Dextrogyre double-helix tangle. a) Perspective view. b-e) Generation of the tangle by the overlapping instability of the Lehmann cluster (twin dislocations).

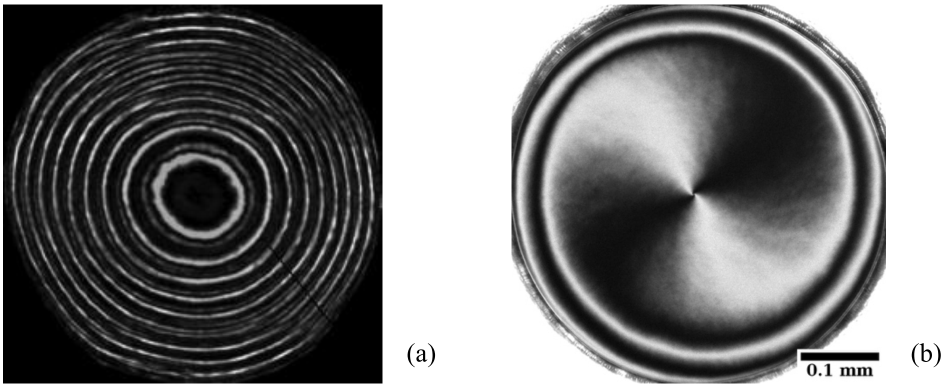
References

[1] P. Pieranski, M. Zeghal, P. Judeinstein, M. H. Godinho, R. Bouffet-Klein, B. Liagre, N. Rouger, *Phys. Rev. Lett.* **131**, 128101 (2023)

Chemical Leslie Effect in Thin Films of Chiral Liquid Crystals

F. Bunel[1], P. Oswald[1*]
[1] *Laboratoire de physique, ENS de Lyon, 69364 Lyon Cedex 07*
[*] *The corresponding author e-mail: patrick.oswald@ens-lyon.fr*

When a flux of foreign molecules passes through a chiral liquid crystal film, the liquid crystal molecules begin to rotate, and flow patterns can emerge.



Examples of patterns observed in a chiral Langmuir monolayer (a) and a free-standing smectic C* film (b). In (a) the director field is non-singular, whereas in (b), it exhibits a +1 disclination at the center of the film. The black and white fringes observed in reflection between crossed polarizers reveal the phase winding.

We investigate these chemical effects in two distinct systems: Langmuir monolayers, where chiral molecules form a two-dimensional nematic phase [1], and free-standing ferroelectric smectic C* films [2,3]. In the first case, the Leslie effect is driven by the evaporation of water molecules from the subphase through the monolayer. In the second case, it is induced by a controlled ethanol flow across the film. Our experiments demonstrate how these systems can be used to measure the two coupling coefficients — chemomechanical and chemohydrodynamical — predicted by Leslie's theory.

References

[1] F. Bunel F., J. Ignès-Mullol, F. Sagues, P. Oswald, Soft Matter, **14**, 4835-4845 (2018).
[2] F. Bunel, P. Oswald, Phys. Rev. E, **107**, 024703 (2023).
[3] F. Bunel, P. Oswald, Phys. Rev. E, **107**, 024704 (2023).

Gold nanoparticle networks in topological defects of smectic liquid crystal

C. Tosarelli[1], H. Jeridi[1,2], J.D. Niyonzima[1, 3], D. Constantin[4], D. Babonneau[5], Y. Prado[1], I. Trimaille[1], M. Treguer-Delapierre[6] and E. Lacaze[1]

[1] Institute de NanoSciences de Paris, CNRS, Sorbonne Université, Paris, France
[2] OMNES Education Research Center, ECE Paris, Paris, France
[3] Physics dep., School of Science, College of Science and Technology, University of Rwanda, Kigali, Rwanda
[4] Université de Strasbourg, Institut Charles Sandron, CNRS UPR022, Strasbourg, France
[5] Dep. Physique et Mechanique des Materiaux, Institut P', Université de Poitiers, France
[6] ICMCB, CNRS, Université de Bordeaux, Pessac, France
Adresse courriel du présentateur: caterina.tosarelli@insp.jussieu.fr

A liquid crystal (LC) is a mesophase where the molecules are free to move as in a fluid, but show a certain degree of order as in a crystal lattice. Under specific conditions, a thin film of LC can form a pattern of flattened hemicylinders that present different kinds of topological defects (1D and 2D defects) strictly oriented along the hemicylinders direction. These defects are able to confine nanoparticles (NPs) [1], leading to the formation of specific networks that are well oriented along the defects [2]. Our aim is to exploit the intrinsic order of this LC matrix to ensure a good orientation and alignment of gold nanoparticles, in order to enhance their optical properties, creating a plasmonic composite. We are currently interested in using gold nanorods coated with thiol-ended polystyrene. Absorption measurements performed with POM reveal that these nanorods prefer to self-assembly side-to-side, either perpendicularly or parallelly to the hemicylinder. The well defined orientation of these networks provides the composite with polarized plasmonic properties (Figure 1). We show that playing with the LC's thickness and nanorod concentration we can induce a preferred orientation of the side-to-side nanorods. This anisotropic arrangement of the nanorods is confirmed also by X-ray diffraction measurements. To better understand the organization of these nanoparticles, the absorption measurements are coupled with numerical simulations that seem to suggest a more complex structure than the side-to-side aggregation, strongly dependent on the number of interacting rods.

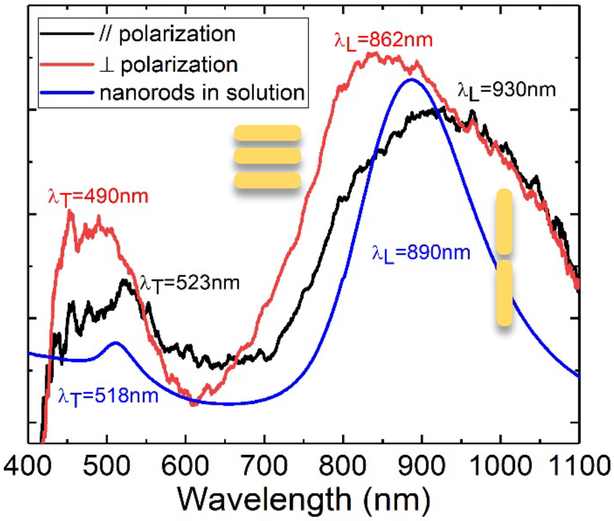


Figure 1. Absorption spectra of AuNR in LC, showing the shift of the resonance wavelength with the polarization of light. The different kind of shift is associated with different kind on nanorod assembly.

Références

[1] Do, *Nano Letters* **20**,3,1598-1606 (2020).
[2] Jeridi et al. *Soft Matter* 18, no. 25 (2022): 4792–4802

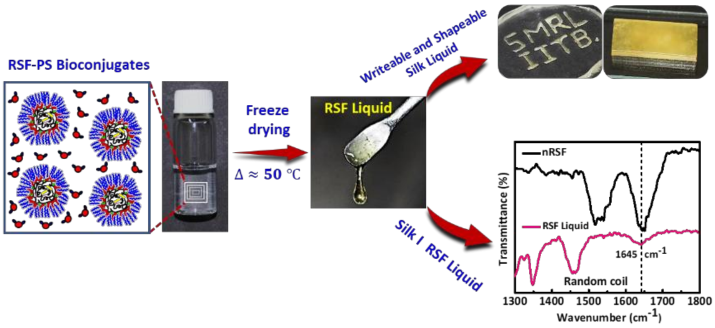
Inhibiting Conformational Transitions of Silk Fibroin via Surface Engineering with polymers: Making Solvent-Free Silk Liquid

Raj Kumar,[1,3] Emmanuel Joseph[2], Anuya. Nisal[2], and Kamendra. P. Sharma*[1]
[1]Department of Chemistry, Indian Institute of Technology Bombay, -400076 India
[2]Polymer Science and Engineering Division, CSIR-NCL, Pune-411008, India.
[3]Paul Pascal Research Center, CNRS, University of Bordeaux-33600 France
Corresponding Author: *k.sharma@chem.iitb.ac.in*

Regenerated Silk Fibroin (RSF) is a biocompatible polymer known for exceptional toughness and high strength, governed by random coil/α-helix dominated silk I conformation.[1] However, processing even dilute solution (≈ 0.1-1 mg mL^{-1}) or aging causes conformational transformation to silk-II (β-sheet). The conformational transition leads to β-sheet aggregation and thus altering its toughness.[2] Therefore, inhibiting the conformation transition and preserving RSF in silk-I is challenging during biomaterial fabrication. Kaplan *et al.* show that annealing with water vapor at 4 °C helps in maintaining the silk I conformation.[3] Recently, Small molecules like curcumin and cyclodextrin interact with RSF chains through hydrogen bonding and hydrophobic interaction, inhibiting the structural conformation.[4] However, the long-term storage stability of silk-I conformation of RSF has not been reported.

Here we show the preservation of silk-I conformation of RSF by redesigning the RSF surface with the polymeric species. An aqueous solution of RSF was modified with polyethylenimine (PEI) and suofonate-tailed PEG-based polymer surfactant (PS), forming RSF bioconjugates (PS-cRSF). Freeze drying followed by heating powered PS-cRSF leads to the formation of solvent-free silk liquid (RSF liquid), which shows solid to liquid transition at 50 °C. Modifying RSF surface with PEI and PS forms a dual coronal shell, inhibiting the interaction between the molecular chain of RSF and preserving the silk I conformation over 8 months. Rheology suggests the viscoelastic and shear thinning behavior of RSF liquid, which is helpful for its applications in injection-based writing and shaping.

Keywords: Bioconjugation, RSF Liquid, Viscoelastic, silk I, writeable and shapeable liquid



References

[1] Shao, Z., Vollrath, F. Surprising strength of silkworm silk. *Nature*, **2002**, *418*, 741-741.

[2] Li, G., Zhou, P., Shao, Z., Xie, X., Chen, X., Wang, H., Chunyu, L., Yu, T. *Eur. J. Biochem*. **2001**, *268*, 6600-6606
[3] Hu, X., Shmelev, K., Sun, L., Gil, E. S., Park, S. H., Cebe, P., Kaplan, D. L. *Biomacromolecules*, **2011**, *12*, 1686-1696.
[4] Ragona, L., Gasymov, O., Guliyeva, A. J., Aslanov, R. B., Zanzoni, S., Botta, C. Molinari, H. BBA-*Proteins Proteom.* **2018**, *1866*, 661-667.
[5] Kumar, R.; Joseph, E.; Chaudhari, A.; Nisal, A.; Sharma, K. P. *ACS Appl. Polym. Mater.* **2022**, *4*, 4699-4708.

I gratefully acknowledge the support and encouragement of my postdoctoral supervisor, Dr. Eric Grelet, in attending this conference.

Study of Thermodynamic Behavior in Polymer–Recycled Liquid Crystal Mixtures

Amina BOURICHE[1] ,Y. Bouayed-Kazi Aouel[1*], U.Maschke[2], L. Bedjaouı-Alachaher[1]

[1] *Laboratoire de Recherche sur les Macromolécules (LRM), Faculté des Sciences, Université Abou-bekr Belkaïd de Tlemcen (UABT), BP 119, 13000 Tlemcen, Algeria,*

[2] *Unité Matériaux et Transformations (UMET), UMR 8207, Université de Lille, CNRS, INRAE, Centrale Lille, F-59000 Lille, France,*

[*] *The corresponding author e-mail: y_kazi2002@hotmail.fr*

This work focuses on the development and characterization of polymer-dispersed liquid crystals (PDLCs) incorporating recycled liquid crystals (RLCs) obtained from end-of-life LCD screens. These hybrid systems combine the mechanical properties of polymers with the optical responsiveness of liquid crystals, offering promising applications in smart materials and electro-optical devices. The use of RLCs contributes to the valorization of complex electronic waste while preserving key optical features such as birefringence and the nematic–isotropic transition. Two types of polymer matrices were studied: polymethylphenylsiloxane (PMPS 40000) and poly(2-ethylhexyl acrylate), both mixed with RLCs in varying compositions. The PDLCs were prepared using the thermally induced phase separation (TIPS) method. Characterization was carried out using polarized optical microscopy (POM), Fourier transform infrared spectroscopy (FTIR), and differential scanning calorimetry (DSC), in order to analyze the structural organization, thermal behavior, and optical properties of the materials. The results highlight the influence of composition on phase transitions and electro-optical performance, contributing to a better understanding of PDLC systems using recycled liquid crystal components.

Keywords: PDLC, recycled liquid crystals, thermal phase separation, FTIR, DSC, POM, electro-optical materials

RECLAIMING FUNCTIONALITY: DIELECTRIC BEHAVIOR OF LIQUID CRYSTALS FROM END-OF-LIFE LIQUID CRYSTAL DISPLAYS

A. Bouriche[1,2], A.Barrera[1], C.Binet[1], F. Dubois[3], Zohra Bouberka[4], Philippe Supiot[1],
C. Foissac[1] and U. Maschke[1*]

[1] Laboratoire de Recherche sur les Macromolécules (LRM), Faculté des Sciences, Université Abou-bekr Belkaïd de Tlemcen (UABT), BP 119, 13000 Tlemcen, Algeria,
[2] Unité Matériaux et Transformations (UMET), UMR 8207, Université de Lille, CNRS, INRAE, Centrale Lille, F-59000 Lille, France,
[3] Unité de Dynamique et Structure des Matériaux Moléculaires (UDSMM), UR 4476, Université du Littoral – Côte d'Opale, CS 80699, 62228 Calais, France,
[4] Laboratoire Physico-Chimie des Matériaux-Catalyse et Environnement (LPCMCE), Université des Sciences et de la Technologie d'Oran Mohamed Boudiaf (USTOMB), BP 1505, El M'naouer, Oran 31000, Algeria,

**Email : ulrich.maschke@univ-lille.fr*

Liquid Crystal Displays (LCDs) have been integral to modern technology, appearing in everything from televisions to mobile phones. In recent years, the recycling of Liquid Crystals (LCs) from end-of-life LCDs has gained significant economic importance, presenting an opportunity to repurpose these organic materials and retain their value.

This study explores the dielectric properties of recycled LCs sourced from industrial LCD recycling processes. The LCs primarily displayed a nematic phase and were tested in their non-purified, purified, and doped forms with diamond nanoparticles (DNPs) at concentrations of 0.05%, 0.1%, and 0.2% by weight. A particular focus was placed on how DNPs influence the behavior of mobile ions within the recycled LCs. Dielectric measurements were performed using an impedance analyzer over a frequency range of 0.1 Hz to 10^6 Hz, and the effects of different anchoring conditions (planar and homeotropic alignments) were also examined. All experiments were conducted at room temperature with a fixed oscillating voltage of 1 V.

The results showed that the dielectric anisotropy of all purified samples was positive, but a noticeable decrease in anisotropy was observed upon doping with DNPs. Furthermore, the DC conductivity values, determined using Jonscher's universal law of dielectric response, revealed that the conductivity of doped LCs was lower compared to undoped and non-purified LCs, regardless of alignment type.

Keywords : end-of-life LCDs; nematic liquid crystals; recycling; dielectric properties.

Thematic Session: Nanocomposite
Disciplinary fields involved: Chemistry, Physics
Keywords: smectic, assembly, gold

Composites nanoparticles/liquid crystals, structure and electro-optical properties

Muyan Zhou1, Myriam Uros2, Jean de Dieu Niyonzima1,3, Haifa Jeridi4,1, Lamya Essaoui1, Caterina Tosarelli1, Alina Vlad5, Alessandro Coati5, Sébastien Royer1, Isabelle Trimaille1, Michel Goldmann1, Bruno Gallas1, Doru Constantin6, David Babonneau7, Yves Garreau4,8, Bernard Croset1, Lydia Sosa-vargas1 and Emmanuelle Lacaze1

1. Sorbonne Université, CNRS, Institut des Nano-Sciences de Paris (INSP), F-75005 Paris 2. Sorbonne Université, CNRS, Institut Parisien de Chimie Moléculaire Paris (IPCM), F-75005 Paris, France 3. Physics Department, School of Science, College of Science and Technology, University of Rwanda, P.O. Box 3900 Kigali, Rwanda 4. ECE Research Center (LyRIDS), ECE Engineering School, 75015 Paris, France 5. Synchrotron SOLEIL, BP 48, L'Orme des Merisiers, 91192 Gif sur Yvette Cedex 6. Institut Charles Sadron, CNRS and Université de Strasbourg, 67034 Strasbourg 7. Université de Poitiers, ISAE-ENSMA, CNRS, PPRIME, Poitiers 8. Université Paris Cité, CNRS, Laboratoire Matériaux et Phénomènes Quantiques (MPQ), F-75013, Paris.

Abstract

Smectic liquid crystal 8CB, assembled on a rubbed polyvinyl alcohol polymer substrate, forms structures known as oily streaks, where smectic layers curve into flattened hemicylinders, creating ribbon-like grain boundary topological defects parallel to the substrate and of width between 300 and 400nm [1]. These defects can confine nanoparticles (NPs), such as gold or semiconductor nanospheres, forming ordered, self-oriented ribbon-like monolayers of NP, of orientation controlled by the rubbed polymer substrate [2]. By controlling solvent evaporation, we demonstrate that the proportion of oily streaks with fewer dislocations increases, promoting the formation of straight, high-quality NP ribbons. Within these ribbons, NPs adopt a hexagonal arrangement. Ribbon length grows with NP concentration, while ribbon morphology depends on NP size and concentration. In previous experiments, nanospheres have successfully formed ribbons confined in the topological defects with various isolating ligands. In this work, we replace these with semiconductive chemical ligands containing conjugated units, which alter both the NP properties and their arrangement within local ribbons. We monitor the localised surface plasmon (LSP) resonance in the smectic oily streaks as a function of the local ribbon structure. Future work will focus on synthesising a broader range of semiconductor chemical ligands and exploring the assembly of diverse nanoparticles within topological defects.

References :

[1] Jeridi H, de Dieu Niyonzima J, Sakr C, et al. The unique orientation of 1D and 2D nanoparticle assemblies confined in smectic topological defects[J]. Soft Matter, 2022, 18(25): 4792-4802.

[2]Do S P, Missaoui A, Coati A, et al. From chains to monolayers: nanoparticle assembly driven by smectic topological defects[J]. Nano Letters, 2020, 20(3): 1598-1606.

Topological metadefects: necklaces made of cholesteric dislocations

P. Pieranski[1,] M. Zeghal[1] and P. Judeinstein[2], M. H. Godinho[3]

[1] *Laboratoire de Physique des Solides, Université Paris Saclay, Orsay, France*
[2] *Université Paris-Saclay, CEA, CNRS, LLB, 91191 Gif-sur-Yvette, France*
[3] *i3N/CENIMAT, NOVA University Lisbon, Portugal*

Classification of defects in ordered systems, based on the homotopy theory, conceived by Gérard Toulouse and Maurice Kléman [1] has a very wide range of applications.

In ref. [2] We illustrated its modus operandi with three experimental examples. We dealt first with dislocations in a dissipative periodic pattern of convection rolls in a shear flow instability in nematics. As the second example we chose the captive disclination loops threaded on polymer fibers immersed in nematics. Third, we focused on objects with double topological character defined for the first time in the generic article coauthored by Gérard Toulouse: the "double et triple anneau" Hopf links made of interlaced dislocation loops in cholesterics.

Finally, we report on the recent discovery of their generalised, beads necklace version made of many bangles threaded, like pearls, on cargo dislocation loops.

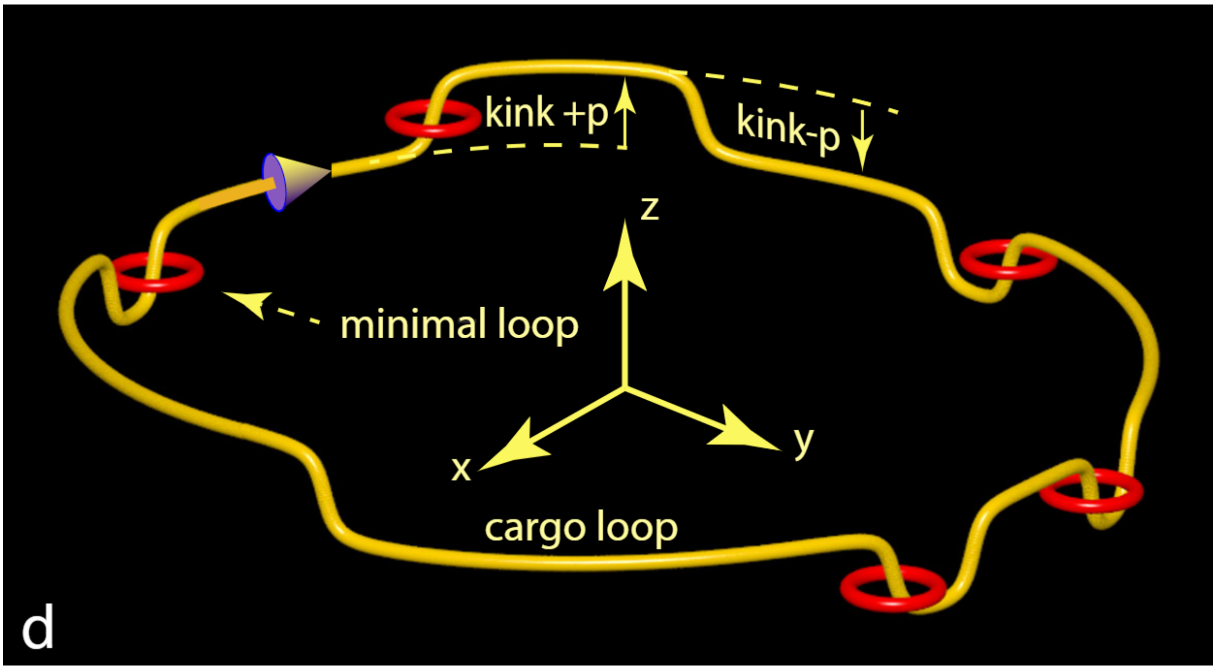


Figure 1: Perspective view of a necklace of bangles tethered on positive kinks of a cargo dislocation loop.

References

[1] G. Toulouse and M. Kleman, *J. Physique Lett*. **37,** 149 (1976)
[2] P. Pieranski, *Comptes Rendus Physique,* **25**, 367 (2024).

Dislocations and disclinations in cholesterics in memoriam of Jacques Friedel and Maurice Kleman

P. Pieranski[1*]
[1] *Laboratoire de Physique des Solides, Université Paris Saclay, Orsay, France*
e-mail: pawel.pieranski@universite-paris-saclay.fr

A large part of the scientific legacy of Maurice Kleman concerns topological defects in liquid crystals. We focus on the very first article of Kleman on liquid crystals coauthored with Jacques Friedel [1] and devoted to linear defects in cholesterics discovered in 1921 by François Grandjean who observed them in wedges made from partially cleaved mica sheets. Kleman and Friedel interpreted the thin (single) and thick (double) Grandjean lines as dislocations with Burgers vectors equal respectively to p/2 (half pitch) or p (whole pitch) and have shown that they are composed of pairs of disclinations that they called τ and λ. We report on a recent work accomplished specifically in memoriam of Maurice Kleman, with the aim to show the beauty of nets of Grandjean lines in wedges made of mica sheets. Using crossed cylindrical sheets, we nucleated in a controlled manner dislocation loops of the two kinds persisting indefinitely independently of the local thickness and of the angle of the wedge. In thin wedges, surprisingly, the double dislocation loops are not smooth but contain one or two cusps corresponding to kinks predicted by Kleman and Friedel. Their presence is a fingerprint of the helicoidal symmetry of cholesterics.

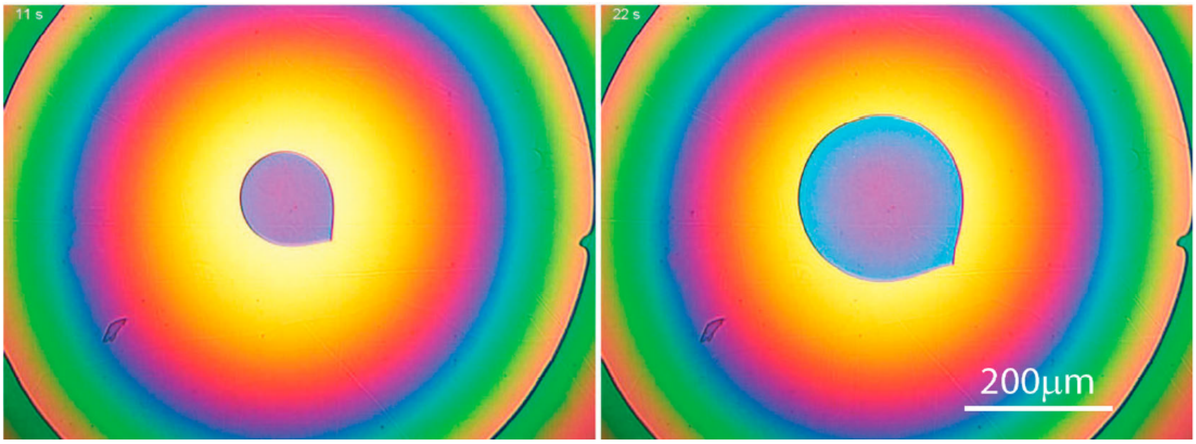


Figure 1: A double dislocation loop containing one cusp corresponding to the kink predicted by Kleman and Friedel.

References

[1] M. Kleman and J. Friedel, *J Phys* **30**, 555 (1969).
[2] P. Pieranski, *Liq. Cryst. Rev.* **10**, 6-33 (2022).

Les suspensions d’argiles smectites forment elles une phase cristal-liquide smectique ?

Karin El Rifaii,[1] Henricus H. Wensink,[1] Ivan Dozov,[1] Thomas Bizien,[2] Laurent J. Michot,[3] Jean-Christophe P. Gabriel,[4] Josef Breu,[5] Patrick Davidson[1]

1 Laboratoire de Physique des Solides, Université Paris-Saclay, CNRS, 91405 Orsay, France.

2 SWING beamline, SOLEIL Synchrotron, 91192 Gif-sur-Yvette, France.

3 Laboratory of Physical Chemistry of Electrolytes and Interfacial Nanosystems (PHENIX), Sorbonne Université, CNRS, 75005 Paris, France.

4 Université Paris-Saclay, CEA,CNRS, NIMBE-LICSEN, 91191 Gif-sur-Yvette, France.

5 Bavarian Polymer Institute and Department of Chemistry, University of Bayreuth, Universitätsstrasse 30, Bayreuth, 95440, Germany.

Les stratégies ascendantes pour la production de nanostructures bien définies reposent souvent sur l'auto-assemblage de particules colloïdales anisotropes (nanofils, nanofeuillets). Ces briques de base peuvent être obtenues par exfoliation dans un solvant de cristaux de basse dimensionnalité. Pour optimiser l’obtention de ces particules anisotropes, la détermination du mécanisme d’exfoliation et de leurs différents stades d'organisation est nécessaire. Nous avons abordé cette question fondamentale en exploitant un système récemment mis au point de fluorohectorite, un minéral argileux smectite qui s’exfolie dans l'eau, ce qui conduit à des dispersions colloïdales de feuillets d'argile monocouches, de très grande taille (≈ 20 µm), à haute dilution. Nous avons montré que lorsque les cristallites d'argile sont dispersés dans l'eau, ils gonflent pour former des empilements périodiques unidimensionnels de feuillets de fluorohectorite, d’épaisseur ≈ 1 nm, avec une fraction volumique très faible (< 1 %) et donc des périodes énormes (> 100 nm) [1]. En utilisant la microscopie optique et la diffusion des rayons X au synchrotron SOLEIL, nous avons établi que ces empilements colloïdaux présentent de fortes similitudes, mais aussi des différences subtiles, avec une phase cristal-liquide smectique. Malgré la forte dilution, les empilements de feuillets, appelés accordéons colloïdaux, sont extrêmement robustes sur le plan mécanique et peuvent subsister pendant des années. De plus, lorsqu'ils sont soumis à des champs électriques alternatifs, ils tournent comme des corps solides, ce qui démontre leur remarquable cohésion interne. En outre, notre modèle théorique rend compte de la variation de la période d'empilement en fonction de la concentration de la dispersion et de la force ionique et explique, en invoquant l'effet Donnan, pourquoi les accordéons colloïdaux sont cinétiquement stables pendant des années et insensibles aux cisaillements et au mouvement brownien. Notre modèle n'étant pas spécifique à un système donné, nous pensons que des accordéons colloïdaux similaires doivent fréquemment apparaitre comme un état intermédiaire au cours de l’exfoliation de cristaux bidimensionnels dans des solvants polaires.

[1] K. El Rifaii, *Langmuir*, **38**, 14563 (2022).