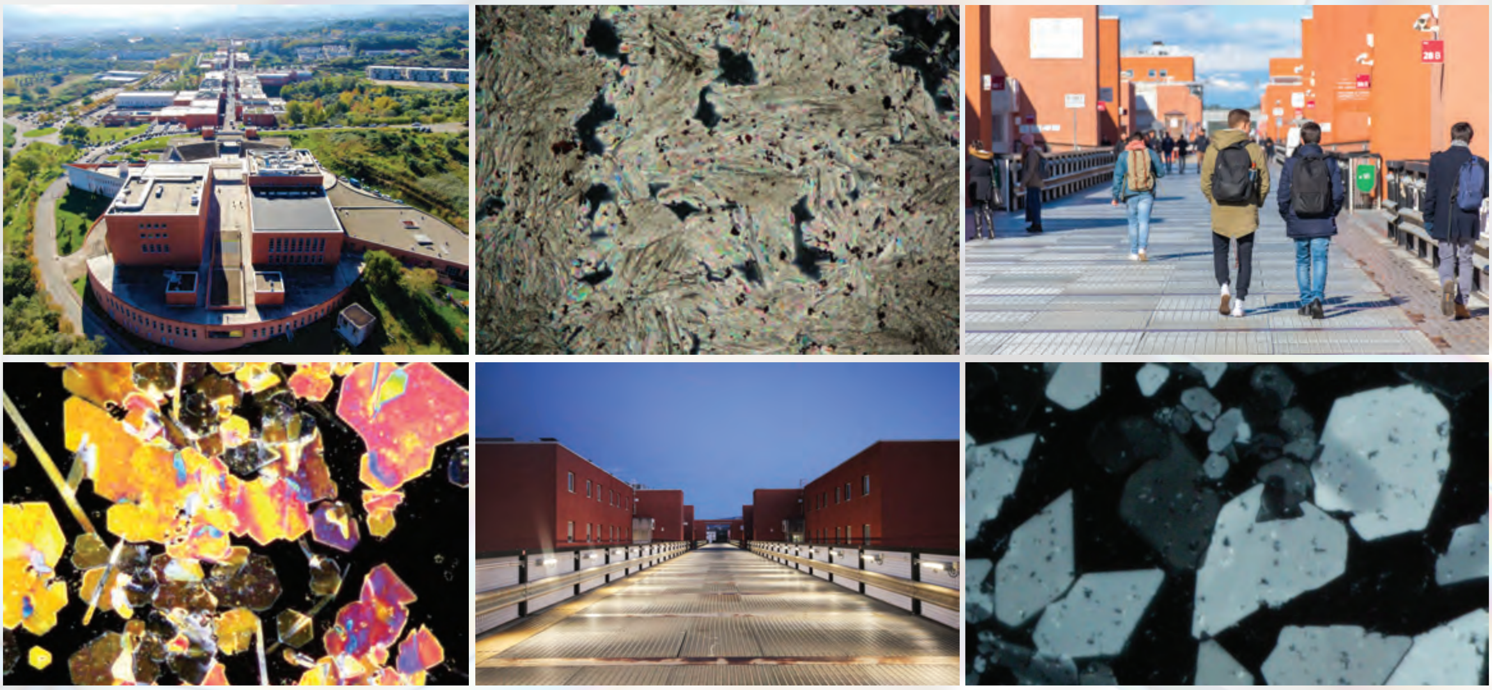
ECLC 2023

16th European Conference on Liquid Crystals

July 10 -14, 2023
UNICAL - Rende (CS), Italy



Abstract Book

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LiCryL
Liquid Crystal Laboratory

BCC MEDIOCRATI
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WWW.SINERGIEANALITICHE.IT
calsystem Strumentazione scientifica e medicale
arintha biotech Biologia cellulare e molecolare
calservice Assistenza tecnica
apotemaforum Centro di informazione e formazione tecnica e scientifica

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Città di Rende

16th European Conference
on Liquid Crystals
JULY 10-14, 2023
UNICAL - RENDE, ITALY

16th edition of the European Conference of Liquid Crystals – ECLC 2023

On behalf of University of Calabria, the Liquid Crystal Laboratory LiCryL, the CNR Institute Nanotec and the Italian Liquid Crystal Society, the 16th edition of the European Conference of Liquid Crystals (ECLC) will be held at the University of Calabria in Rende (Italy) from 10th to 14th of July 2023.

Conference website: **https://www.eclc2023.eu**
Contact: **info@eclc2023.eu**

With its dynamic environment due to the presence of lively Unical Campus, Rende represents a very convenient site to enjoy the many beauties of Calabria which has been recently declared by TIME magazine one of the world top 50 destinations to visit.
The University of Calabria or Unical was established in 1968 with the aim of rooting in this area a strategic resource for the development of Calabria, capable of creating prospects for cultural, social and economic growth for its students and their families.

ECLC - European Conferences on Liquid Crystals

European Conferences on Liquid Crystals (ECLC) are the traditional forums of European scientists working in the interdisciplinary field of Liquid Crystals, Soft Anisotropic Materials and now also Active Matter, bringing together specialists from academic and industrial research centers across the world.

This traditional Conference dates back to 1991. In the 21th century they were held in Germany (Halle, 2001), Spain (Jaca, 2003), Italy (Sesto, 2005), Portugal (Lisbon, 2007), France (Colmar, 2009), Slovenia (Maribor, 2011), Greece (Rodos, 2013) and United Kingdom (Manchester, 2015), Russia (Moscow, 2017) and Poland (Wrocław, 2019).

After a forced stop, due to Covid pandemic, the 16th European Conference on Liquid Crystals restarts on 2023 at the University of Calabria in Rende (Italy) from 10th to 14th of July 2023.

Scientific Topics

The main scientific topics of ECLC 2023 are:

- Confined and Self-assembled systems
- Sustainable and Biological materials
- Complex, Unconventional and Chiral LC Phases\
- Ferroelectric Nematics
- Active Matter
- LCs in Photonics
- Responsive and Reactive LCs
- Exotic Phenomena with LCs
- Design and Synthesis of LC Materials
- Theory and Simulations of LC Systems
- Innovative Technologies
- Topology and Defects
- Other topics related to LCs.

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Conference Proceedings

A special issue of ***Liquid Crystals*** (https://www.tandfonline.com/journals/tlct20) will be devoted to ECLC 2023.

Liquid Crystals publishes accounts of original research concerned with all aspects of liquid crystal science and technology, including experimental and theoretical studies ranging from molecular design and synthesis to applications engineering. The journal focus is on liquid crystalline supermolecular organization and self-assembly in a wide range of materials, including thermotropic, lyotropic, interfacial, chiral, ferroelectric, polymer, micro/nanocomposite, biological and related soft-matter liquid crystal systems.

All submitted manuscripts will be subject to peer review by independent, anonymous expert referees.

The ECLC 2023 organizers thanks prof. Corrie T. Imrie, Editor of ***Liquid Crystals***, for his support.

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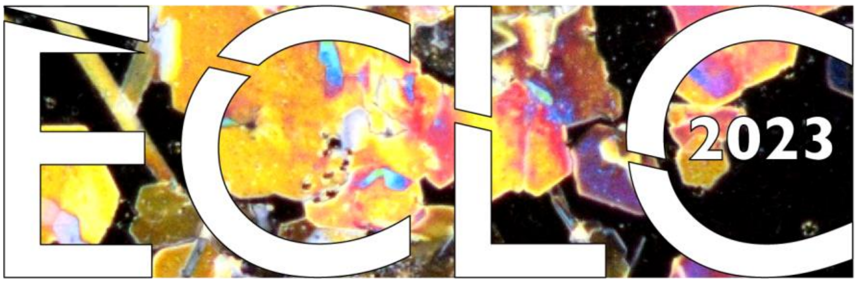
16th European Conference on Liquid Crystals



DETAILED PROGRAM

Università della Calabria
Rende (CS) - Italy, July 10 - 14, 2023

Hall A

	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY		FRIDAY
8:30-9:30		REGISTRATION and OPENING					
9:30-10:10		13- R. BARTOLINO	11- N. TABIRYAN	6- F. SIMONI	7- E. VIRGA	9:30-10:05	9- E.I. SZERB
10:10-10:45		4- R. MANDLE	7- A. SCHENNING	6- G. ASSANTO	6- M. GEDAY	10:05-10:35	2- S. FERNANDES
10:45-11:15		4- J. MACLENNAN	4- A. EREMIN	4- V. NOVOTNA	6- R. KOWERDZIEJ	10:35-10:55	2- O. SKELTON
11:15-11:40		*coffee break*	*coffee break*	*coffee break*	*coffee break*	10:55-11:15	10- G. SAIELLI
11:50-12:10		4- A. EMELYANENKO	4- P. SALAMON	9- N. GODBERT	6- J. PARKA	11:15-11:45	*coffee break*
12:10-12:30		4- A. ERKOREKA	4- A. CHRZANOWSKA	9- M. LEHMANN	6- K. NEYTS		CLOSING REMARKS & Awards
12:30-12:50		4- Y.T. HSIAO	4- D.P. SINGH	9- L. REBER	6- M. MUSZYŃSKI	11:45-13:00	
12:50-13:10		4- E. CRUICKSHANK	4- M. WILSON	9- R. ROSSI	6- A. MAZZULLA		
13:10-13:30		4- H. NISHIKAWA	4- N. YADAV	9- Y. SHIMIZU	6- W. ZHENG		
13:30-15:30		*Lunch break*	*Lunch break*	*Lunch break*	*Lunch break*	13:00-15:00	*Lunch break*
15:30-16:00		4- T. BELLINI	4- L. LUCCHETTI	4- A. MERTELJ	6- S. NOCENTINI		
16:00-16:20		4- P. MEDLE RUPNIK	7- S. DONATO	4- N. SEBASTIAN	6- B. AUDIA		
16:20-16:40		1- H. NÁDASI	7- D. MARTELLA	6- G. STRANGI	1- M. HERBST		
16:40-17:00		Coffee break & Poster Session	7- T. RITACCO	*coffee break*	*coffee break*		
17:00-17:20			Excursion to Cosenza & Villa Rendano Light Dinner	Barbieri Restaurant Altomonte Gala Dinner	1- L. ESSAOUI		
17:20-17:40							
17:40-18:30							
19:30-22:30	Registration and Light Welcome Dinner						

Hall B

	SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY		FRIDAY
8:30--9:30		REGISTRATION and OPENING					
9:30-10:10		Plenary in Hall A	Plenary in Hall A	Plenary in Hall A	Plenary in Hall A	9:30-10:05	5- M. RAVNIK
10:10-10:45		11- E. BRASSELET	12- E. LACAZE	5- T. LOPEZ-LEON	6- J. SZCZYTKO	10:05-10:35	1- T. FRACCIA
10:45-11:15		11- L. DE SIO	10- L.R. EVANGELISTA	5- E. GRELET	4- A. JAKLI	10:35-10:55	1- L. HONAKER
11:15-11:40		*coffee break*	*coffee break*	*coffee break*	*coffee break*	10:55-11:15	3- T. ORLOVA
11:40-12:10		12- S. ČOPAR	10- V. RESHETNYAK	3- E. GORECKA	3- E. OTÓN	11:15-11:45	coffee *break*
12:10-12:30		12- J. NIYONZIMA	10- L. DAL COMPARE	5- M.T. MÁTHÉ	3- P. PIERANSKI	11:45-13:00	CLOSING REMARKS & Awards
12:30-12:50		12- D. BELLER	10- R. HENDRIKSE	5- S.R. SEYEDNEJAD	3- S. RANI		
12:50-13:10		1- T. MADELEINE	10- G. NEGRO	5- Z. VALEI	3- R. WALKER		
13:10-13:30		1- C. TOSARELLI	10- M. OSIPOV	5- L. HEAD	3- R. WITTMANN		
13:30-15:30		*Lunch break*	*Lunch break*	*Lunch break*	*Lunch break*	13:00-15:00	*Lunch break*
15:30-16:00		1- A. CONCELLON	1- O. LAVRENTOVICH	3- I. SMALYUKH	6- D. LUCCHETTA		
16:00-16:20		1- B. ZAPPONE	10- A. FERRARINI	3- M. MARINČIČ	13- A. GOLEMME		
16:20-16:40		1- S. LIU	10- G. ZHAO	3- S. PAPARINI	13- P. DE LA ROSA		
16:40-17:00		Coffee break & Poster Session	2- F. ZACCAGNINI	*Coffee break*	*Coffee break*		
17:00-17:20			Excursion to Cosenza & Villa Rendano Light Dinner	Barbieri Restaurant Altomonte Gala Dinner	13- M. LAVRIČ		
17:20-17:40					13- A. PEDRINI		
17:40-18:30					13- S.S. VARYTIMIADOU		
19:30-22:30	Registration and Light Welcome Dinner						

Topics

Timing
Plenary 35’+5’
Keynote 30’+5’
Invited 25’+5’
Oral 15’+5’

1- Confined and Self-assembled systems; 2- Sustainable and Biological materials; 3- Complex and Chiral LC Phases; 4- Ferroelectric Nematics; 5- Active Matter; 6- LCs in Photonics; 7- Responsive and Reactive LCs; 9- Design and Synthesis of LC Materials; 10- Theory and Simulations of LC Systems; 11- Innovative Technologies; 12- Topology and Defects; 13- Other topics related to LCs

HALL A

MONDAY, July 10th 2023		
8:30 – 9:30	**Registration and Opening Ceremony**	
Other topics related to LCs		*Chair: R. Barberi*
9:30 – 10:10	**PL:** R. Bartolino	An historical and philosophical presentation of the birth and growth of the Liquid Crystals - Soft Matter community at Rende, Calabria, Italy: the first ten years
Ferroelectric Nematics		
10:10 – 10:45	**KL:** R. Mandle	Automated flow synthesis of algorithmically designed ferroelectric nematogens
10:45 – 11:15	**IL:** J. Maclennan	From ferroelectric nematics to smectics
11:15 – 11:40	*Coffee Break*	
Ferroelectric Nematics		*Chair: G. Assanto*
11:50 – 12:10	A. Emelyanenko	Ferroelectric and antiferroelectric splay nematic phases in a liquid crystal composed of polar molecules
12:10 – 12:30	A. Erkoreka	Effect of the sample thickness on the measured dielectric spectra of a ferroelectric nematic liquid crystal
12:30 – 12:50	Y. T. Hsiao	Ferroelectric nematic liquid crystal for fast switching optical components
12:50 – 13:10	E. Cruickshank	The influence of terminal chain length on the formation of the ferroelectric nematic phase
13:10 – 13:30	H. Nishikawa	Nano-clustering over phase transitions in diastereomerically-stabilized ferroelectric nematics
13:30 – 15:30	*Lunch Break*	
Ferroelectric Nematics		*Chair: G. Palermo*
15:30 – 16:00	**IL:** T. Bellini	Electric field guiding and polarization switching in microchannel-confined ferroelectric nematics
16:00 – 16:20	P. Medle Rupnik	Flow-mediated mechano-electric phenomena in ferroelectric nematic liquid crystals
Confined and Self-assembled systems		
16:20 – 16:40	H. Nádasi	Liquid crystal magnets: fine-tuning nanoscale properties and dynamics
16:40 – 18:30	*Coffee Break & POSTER SESSION*	

HALL B

MONDAY, July 10th 2023		
8:30 – 9:30	**Registration and Opening Ceremony (in HALL A)**	
Innovative Technologies		*Chair: M. Giocondo*
10:10 – 10:45	**KL:** E. Brasselet	Light-directed structuring of liquid crystals
10:45 – 11:15	**IL:** L. De Sio	Photo-thermal controlled optical absorber based on liquid crystal metasurfaces
11:15 – 11:40	*Coffee Break*	
Topology and Defects		*Chair: T. Fraccia*
11:40 – 12:10	**IL:** S. Čopar	Shaping nematic droplets with surface tension
12:10 – 12:30	J. Niyonzima	Synchrotron GISAXS study of the effect of thickness on smectic A liquid crystal topological defects
12:30 – 12:50	D. Beller	Defect evolution in the smectic A-to-nematic phase transition in geometrically patterned confinement
Confined and Self-assembled systems		
12:50 – 13:10	T. Madeleine	Control of long-range gold nanoparticles networks in liquid crystals and their topological characterization
13:10 – 13:30	C. Tosarelli	Order and disorder induced by smectic liquid crystal topological defects on gold nanoparticles networks
13:20 – 15:30	*Lunch Break*	
Confined and Self-assembled systems		*Chair: A. Mazzulla*
15:30 – 16:00	**IL:** A. Concellon	Dynamic Complex Liquid Crystal Emulsions
16:00 - 16:20	B. Zappone	Strength from defects: Topological barriers to defect nucleation generates large mechanical forces in a cholesteric
16:20 - 16:40	S. Liu	Reconfiguration of blue phase liquid crystal by photoalignment
16:40 – 18:30	*Coffee Break & POSTER SESSION*	

HALL A

TUESDAY, July 11th 2023		
Innovative Technologies		*Chair: C. P. Umeton*
9:30 – 10:10	**PL:** N. Tabiryan	Optics Unlimited
Responsive and Reactive LCs		
10:10 – 10:45	**KL:** A. Schenning	Stimuli-responsive Hydrogen-Bonded Liquid Crystalline Elastomers
Ferroelectric Nematics		
10:45 – 11:15	**IL:** A. Eremin	Polarity effects in ferroelectric nematics and their hybrids in bulk and confinement
11:15 – 11:40	*Coffee Break*	
Ferroelectric Nematics		*Chair: L. De Sio*
11:50 – 12:10	P. Salamon	Ramification and labyrinth instabilities in a ferroelectric nematic fluid exposed to electric fields
12:10 – 12:30	A. Chrzanowska	Onsager theory of perfectly aligned rod like particles with longitudinal dipoles - bifurcation analysis approach
12:30 – 12:50	D.P. Singh	Thermal conductivity of RM 734 ferroelectric nematic material at the ferroelectric-ferroelastic phase transition
12:50 – 13:10	M. Wilson	The structure of the ferroelectric nematic phase: insights from molecular dynamics simulations
13:10 – 13:30	N. Yadav	Comparison between three ferronematic compounds with different phase sequence
13:30 – 15:30	*Lunch Break*	
Ferroelectric Nematics		*Chair: T. Bellini*
15:30 – 16:00	**IL:** L. Lucchetti	Ferroelectric sessile droplets on ferroelectric solids: electromechanical instability and other phenomena
Responsive and Reactive LCs		
16:00 - 16:20	S. Donato	Multi-responsive microstructures based on Liquid Crystalline Networks
16:20 - 16:40	D. Martella	Cell instructive polymers based on liquid crystals
16:40 -17:00	T. Ritacco	Tuning LCs photoresists during microfabrication
17:00 – 22:30	*Excursion to Cosenza & Villa Rendano Light Dinner*	

HALL B

TUESDAY, July 11th 2023		
Topology and Defects		*Chair: B. Zappone*
10:10 – 10:45	**KL:** E. Lacaze	Smectic liquid crystal topological defects, instabilities and their interactions with nanoparticles
Theory and Simulations of LC Systems		
10:45 – 11:15	**IL:** L.R. Evangelista	Anomalous diffusion approach to electrical impedance response of liquid crystals
11:15 – 11:40	*Coffee Break*	
Theory and Simulations of LC System		*Chair: L. Evangelista*
11:40 – 12:10	**IL:** V. Reshetnyak	Excitation and tuning of optical Tamm states in a metal – polymer – liquid crystal stack
12:10 – 12:30	L. Dal Compare	Stabilization of dense liquid crystalline phases by electrostatic interactions: a molecular dynamics study
12:30 – 12:50	R. Hendrikse	Using many-body dissipative particle dynamics to predict the properties of surfactant systems
12:50 – 13:10	G. Negro	Cholesteric shells: two-dimensional blue fog and finite quasicrystals
13:10 – 13:30	M. Osipov	Electrostatic effects and the origin of ferroelectric ordering in polar nematics
13:30 – 15:30	*Lunch Break*	
Confined and Self-assembled systems		*Chair: M.P. De Santo*
15:30 – 16:00	**IL:** O. Lavrentovich	Shape and Dynamics of Nematic Droplets
Theory and Simulations of LC Systems		
16:00 - 16:20	A. Ferrarini	The elasticity of lyotropic liquid crystal polymers and colloids
16:20 - 16:40	G. Zhao	Order parameter modelling using molecular simulation techniques
Sustainable and Biological materials		
16:40 -17:00	F. Zaccagnini	Gold nanorods-based biosensor with photo-responsive liquid crystals enables the detection of harmful pathogens in potable water
17:00 – 22:30	*Excursion to Cosenza & Villa Rendano Light Dinner*	

HALL A

WEDNESDAY, July 12th 2023		
LCs in Photonics		*Chair: G. Strangi*
9:30 – 10:10	**PL:** F. Simoni	Advancements in Optics and Photonics of Liquid Crystals
10:10 – 10:45	**KL:** G. Assanto	Nematicons, from optics to photonics
Ferroelectric Nematics		
10:45 – 11:15	**IL:** V. Novotna	Ferroelectric nematic phase formed by dimethylamino-terminated molecules
11:15 – 11:40	*Coffee Break*	
Design and Synthesis of LC Materials		*Chair: A. Crispini*
11:50 – 12:10	N. Godbert	Iridium (III) water-soluble cationic complexes between gels and lyotropic liquid crystals: A new class of chromonic liquid crystals?
12:10 – 12:30	M. Lehmann	Record charge mobility in the nematic phase of a biaxial nematogen
12:30 – 12:50	L. Reber	Supramolecular click mechanism and fullerene-substituted porphyrin star mesogens – a success story?
12:50 – 13:10	R. Rossi	3D printing of Liquid Crystal Elastomers for the development of artificial muscles
13:10 – 13:30	Y. Shimizu	Dynamic change of molecular conformation generating a variation of liquid crystalline phases for triphenylene mesogens with peripheral alkoxyazobenzenes
13:30 – 15:30	*Lunch Break*	
Ferroelectric Nematics		*Chair: L. Lucchetti*
15:30 – 16:00	**IL:** A. Mertelj	Photopatterning for the design of domains in ferroelectric nematic liquids
16:00 - 16:20	N. Sebastian	Exploiting flexoelectric coupling in RM734 and DIO: similarities and differences
LCs in Photonics		
16:20 - 16:40	G. Strangi	All-optical tunability of metalenses permeated with liquid crystals
16:40 – 17:00	*Coffee Break*	
17:00 – 22:30	*Barbieri Restaurant Altomonte Gala Dinner*	

HALL B

WEDNESDAY, July 12th 2023		
Active Matter		*Chair: C.M. Tone*
10:10 – 10:45	**KL:** T. Lopez-Leon	Towards autonomous micromachines powered by active nematics
10:45 – 11:15	**IL:** E. Grelet	Bacterial micro-swimmers in colloidal liquid crystals
11:15 – 11:40	*Coffee Break*	
Complex and Chiral LC Phases		*Chair: E. Otón*
11:40 – 12:10	**IL:** E. Gorecka	Complex twist bend smectic phases
Active Matter		
12:10 – 12:30	M.T. Máthé	Active matter state of a ferroelectric nematic liquid crystal
12:30 – 12:50	S.R. Seyednejad	Nematic flow induced by active surface anchoring
12:50 – 13:10	Z. Valei	Active nematic-induced dynamics of passive polymers
13:10 – 13:30	L. Head	Interplay of active nematic defects and flow structures
13:30 – 15:30	*Lunch Break*	
Complex and Chiral LC Phases		*Chair: P.Pieranski*
15:30 – 16:00	**IL:** I. Smalyukh	From chiral nematics to knotted chiral meta matter
16:00 - 16:20	M. Marinčič	Numerical modelling of skyrmions in blue phase iii
16:20 - 16:40	S. Paparini	Contrasting quadratic and quartic elastic theories for Chromonics
16:40 – 17:00	*Coffee Break*	
17:00 – 22:30	*Barbieri Restaurant Altomonte Gala Dinner*	

HALL A

THURSDAY, July 13th 2023		
Responsive and Reactive LCs		*Chair: M. Giocondo*
9:30 – 10:10	**PL:** E. Virga	Photoresponsive Nematic Elastomers
LCs in Photonics		
10:10 – 10:45	**KL:** M. Geday	Light with a twist
10:45 – 11:15	**IL:** R. Kowerdziej	Electrically-Controlled Fano-Resonant Dual-Band Plasmon Induced Transparency Liquid Crystal Terahertz Meta-Switch
11:15 – 11:40	*Coffee Break*	
LCs in Photonics		*Chair: M. Geday*
11:50 – 12:10	J. Parka	Hyperbolic metamaterials for enhancement spontaneous emission engineering
12:10 – 12:30	K. Neyts	Periodic and multi-step photoalignment to obtain 3d liquid crystal structures
12:30 – 12:50	M. Muszyński	Liquid crystal optical microcavity with built-in uniform lying helix as a platform for tunable one-dimensional photonic potential with spin-orbit interaction
12:50 – 13:10	A. Mazzulla	Photonics and optomechanics of core-shell mesogenic-metallic particles
13:10 – 13:30	W. Zheng	Optically generated microstructures in diacrylate polymer networks using a two-photon initiating system
13:30 – 15:30	*Lunch Break*	
LCs in Photonics		*Chair: P. Pagliusi*
15:30 – 16:00	**IL:** S. Nocentini	Polymer stabilized liquid crystals for linear and nonlinear photonics
16:00 - 16:20	B. Audia	Photoinduced birefringence driven by polarization patterning in liquid crystalline triblock copolymers
Confined and Self-assembled systems		
16:20 – 16:40	M. Herbst	Micellar lyotropic liquid crystalline physical gels – a new kind of anisotropic hydrogels
16:40 – 17:00	*Coffee Break*	
17:00 – 17:20	L. Essaoui	Dynamics of 2D-ribbons in liquid crystal topological defects

HALL B

THURSDAY, July 13th 2023		
LCs in Photonics		*Chair: A. De Luca*
10:10 – 10:45	**KL:** J. Szczytko	Topological photonics with liquid crystal microcavities: control over the spin-orbit coupling of light
Ferroelectric Nematics		
10:45 – 11:15	**IL:** A. Jakli	Electromechanical effects in ferroelectric nematic liquid crystals
11:15 – 11:40	*Coffee Break*	
Complex and Chiral LC Phases		*Chair: R. Caputo*
11:50 – 12:10	**IL:** E. Otón	Peculiar chiral liquid crystal structures in photonic applications: from photonic crystals to microlasers
12:10 – 12:30	P. Pieranski	Folds and tangles of dislocation loops in cholesterics
12:30 – 12:50	S. Rani	Observation of helical self-assembly in cyclic triphosphazene-based columnar liquid crystals bearing chiral mesogenic units
12:50 – 13:10	R. Walker	New investigations into the twist-bend smectic phases (SmCTB)
13:10 – 13:30	R. Wittmann	Particle-resolved topology of colloidal smectics
13:30 – 15:30	*Lunch Break*	
LCs in Photonics		*Chair: N. Godbert*
15:30 – 16:00	**IL:** D. E. Lucchetta	Distributed feedback lasing from soft matter: exploring polymer dispersed liquid crystals, chiral liquid crystal microfluidic droplets, and photomobile polymers
Other topics related to LCs		
16:00 - 16:20	A. Golemme	On the origin of high charge mobility in discotic nematic mesophases formed by porphyrin-core dendrimers: an nmr study
16:20 - 16:40	P. de la Rosa	Advancements on liquid crystal-based reflectarray antennas in mm-wave
16:40 – 17:00	*Coffee Break*	
17:00 – 17:20	M. Lavrič	The elastocaloric effect in main-chain liquid crystal elastomers of different crosslinking compositions
17:20 – 17:40	A. Pedrini	Quasi-Uniform Nematic Fields
17:40 – 18:00	S.S. Varytimiadou	Lyotropic nematic liquid crystals: interplay between micellar shape and elasticity

HALL A

FRIDAY, July 14th 2023		
Design and Synthesis of LC Materials		*Chair: M. La Deda*
09:30 – 10:05	**KL:** E. J. Szerb	Metallomesogens from design to functional properties
Sustainable and Biological materials		
10:05 – 10:35	**IL:** S. Fernandes	Cellulose-based nanocomposites for anticounterfeiting applications
10:35 – 10:55	O. Skelton	Sustainable Formulations: Cellulose based Colloid-nematic Gels
Theory and Simulations of LC Systems		
10:55 – 11:15	G. Saielli	phase behaviour of charged Gay-Berne/Lennard-Jones mixtures
11:15 – 11:45	*Coffee Break*	
11:45 – 13:00	Closing remarks & Awards	
13:00 – 15:00	*Lunch Break*	

HALL B

FRIDAY, July 14th 2023		
Active Matter		*Chair: F. Ciuchi*
9:30 – 10:05	**KL:** M. Ravnik	Active and driven nematic topological defects
Confined and Self-assembled systems		
10:05 – 11:35	**IL:** T. Fraccia	Multiphase DNA based liquid - liquid crystalline phase separated systems
10:35 – 10:55	L. Honaker	Developing biological sensors with oleosin-stabilized nematic liquid crystal droplets
Complex and Chiral LC Phases		
10:55 – 11:15	T. Orlova	Topological detection for revealing individual and collective skyrmion transformations in their dynamic assemblies
11:15 – 11:40	*Coffee Break*	
11:45 – 13:00	Closing remarks & Awards	
13:00 – 15:00	*Lunch Break*	

General Index

GENERAL INDEX

Plenary Speakers

An historical and philosophical presentation of the birth and growth of the Liquid Crystals - Soft Matter community at Rende, Calabria, Italy: the first ten years

Roberto Bartolino*

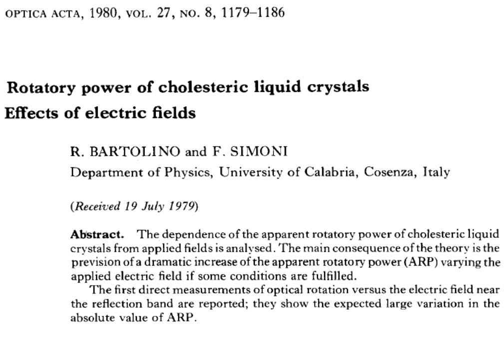
Physics Department, University of Calabria, Rende 87036, CS, Italy
and
CNR-Nanotec, c/o University of Calabria, Rende 87036, CS, Italy

The start of a competent scientific group in a completely new university without any academic tradition was facilitated by a close and friendly collaboration with established international research groups. This friendly attitude has been maintained to foster relations with the European and global Liquid Crystal communities.

At the national level, growth was driven by alignment with the scientific and political programs of two new national organizations: the Institute of Nanostructured Materials (INSTM) for chemists, and the Institute for the Physics of Matter (INFM) for physicists. Ten years later, these organizations were incorporated into the national CNR (National Research Council).

As a result of strong interactions with these two organizations, three main development pathways emerged:

1. Scientific attitude: embracing interdisciplinarity has become a priority, promoting not only closer collaboration between chemists and physicists, but also with other scientific fields facing similar problems or utilizing different technologies and production methods.
2. Creation of Large-Scale Facilities: recognizing the needs and knowledge of the scientific community, efforts were made to establish large-scale facilities, that could benefit the entire scientific community, at least at national level.
3. Focus on applications and spinoff companies: the need emerged to explore potential applications of the academic research and to promote the growth of new companies.



OPTICA ACTA, 1980, VOL. 27, NO. 8, 1179–1186

Rotatory power of cholesteric liquid crystals
Effects of electric fields

R. BARTOLINO and F. SIMONI
Department of Physics, University of Calabria, Cosenza, Italy

(*Received 19 July 1979*)

Abstract. The dependence of the apparent rotatory power of cholesteric liquid crystals from applied fields is analysed. The main consequence of the theory is the prevision of a dramatic increase of the apparent rotatory power (ARP) varying the applied electric field if some conditions are fulfilled.

The first direct measurements of optical rotation versus the electric field near the reflection band are reported; they show the expected large variation in the absolute value of ARP.

Figure 1. The pioneering beginning of Liquid Crystal research at University of Calabria

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* Author for Correspondence: bartolino.fis@gmail.com

Advancements in Optics and Photonics of Liquid Crystals

Francesco Simoni

Università Politecnica delle Marche, Ancona, Italy
and Istituto di Scienze Applicate e Sistemi Intelligenti - CNR, Pozzuoli, Italy

The few physical concepts underpinning the liquid crystal displays allowed the development of several branches in research related to optical properties of liquid crystalline materials, which resulted also attractive for other area of applications. Giving a look to this broad research landscape some of the most relevant scientific achievements will be underlined with a look to future emerging technologies.

A place apart is allocated to nonlinear optics, the new research field born after the discovery of collective molecular reorientation induced by light in nematic liquid crystals. The main concepts will be highlighted, and some relevant phenomena will be discussed, including the presentation of the recent results.

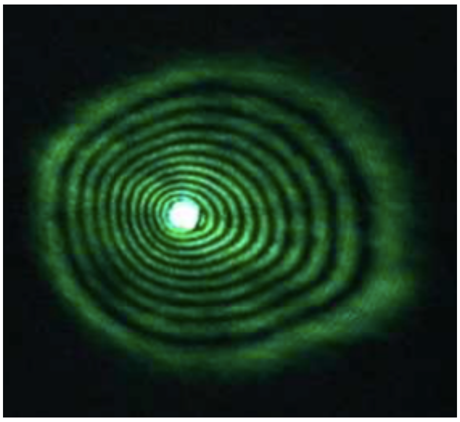

Figure 1. Typical ring pattern originated by self-phase modulation in a nematic liquid crystal.

* Correspondence: f.simoni@photomat.it
Website: www.photomat.it

Optics Unlimited

Nelson Tabirian

BEAM Engineering for Advanced Measurements Co., Orlando, Florida, USA

LiDARs are stupid, according to Elon Musk. He might be right, but he may not have been following developments in optics… It is true that conventional optical technologies are not efficient enough, compact and inexpensive enough to map the ambient fast and accurate enough for safe enough auto-navigation. But there is a great need for it. And there is a great need for adaptive glasses, ultralight large optics, switchable optics, sensor and metrology optics, etc., etc.

The statement of a philosopher that the laws of geometry would have been altered if they inconvenienced our lives may be proving right again, this time with the technology that overcomes most limitations of present-day optics. And since liquid crystalline materials and technologies are in the hearth of this millennial breakthrough, ECLC 2023 is one of the best venues to present and discuss the underlying principles, capabilities, and superiority of the fourth generation of optics over both classical as well as metamaterial-based devices.

Utilizing geometrical phase modulation, the fourth-generation optics provides practically unlimited opportunities to meet the needs of modern and emerging technologies and opens up new avenues for innovations and applications. Above all, it has proven to be the most environmentally friendly, requiring only milligrams of materials per square cm of aperture, and only minutes for fabrication. And the fabrication tools are affordable to most research and educational organizations (including high schools) …

There are indeed, and we will discuss as well fundamental and technological limitations since even Space has limits (according to pre-JWST Big Bang theory). In our case, the sky is the limit which is no wonder given the development has been fueled by the US Air Force Research Laboratory in close collaboration with Jonathan Slagle, Michael McConney, Timothy J. Bunning, and other advanced research organizations and researchers.

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* Author for Correspondence: info@beamco.com

Photoresponsive Nematic Elastomers

Epifanio G. Virga*

Department of Mathematics, University of Pavia, 27100 Pavia, Italy

Illumination of photoisomerizable molecules, such as azobenzene and other dyes, produces a change in their shape, typically from straight to bent rods, the former identified as *trans*-state and the latter as *cis*-state. When these molecules are dispersed in the polymer network of a nematic elastomer, their photoisomerization produces a disrupting effect on surrounding photoinert molecules (which remain straight), decreasing their degree of nematic order and thus inducing a spontaneous deformation of the whole polymer network. Such a disruption of order is reversible. Photoresponsive molecules do not stay indefinitely in their *cis*-state; they decay by thermal relaxation to the *trans*-state. Once in that state, their reacquired rod-like shape does no longer contrast the alignment of photoinert molecules, so that nematic order can be reinstated and deformation recovered. In these materials, a desired persistent deformation results from a delicate statistical dynamic equilibrium.

The lecture will review a continuum theory that builds upon a statistical mechanics model put forward by Corbett and Warner [1]. The theory is then applied to the equilibrium of a photoresponsive ribbon. The spontaneous deformation induced by illumination is proved *not* to be monotonically dependent on the light intensity I. The ribbon's deflection first increases with increasing I, as expected, but then decreases and abruptly ceases altogether at a critical value of I. Perhaps surprisingly, there is a critical value of the ribbon's length, depending only on the degree of cross-linking in the material, below which no deflection can be induced in the ribbon, no matter how intense is the light shone on it. These are features that distinguish the activation mechanism described by this model from the more common thermal activation of nematic elastomers.

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* Author for Correspondence: eg.virga@unipv.it

Keynote Speakers

Nematicons, from optics to photonics

Gaetano Assanto

NooEL - *Nonlinear Optics and OptoElectronics Lab*, DIIEM-University Roma Tre, Rome 00146, Italy

Nematicons or spatial optical solitons in nematic liquid crystals for more than two decades [1] have been a rich playground for soliton scientists, applied mathematicians, nonlinear physicists, material experts, photonic engineers [2-5]. They are nonlocal robust self-confined light wave-packets which, propagating in a birefringent fluid subject to reorientation, can guide co-polarized signals and undergo external control upon the interaction with light, voltage, magnetic field, temperature.

In this talk I will overview the fundamental properties and some notable applications of nematicons, outlining some of the relevant achievements with optical solitary waves in soft matter [6-10].

Figure 1 displays an example of wave/particle duality of light in nematic liquid crystals, where two extraordinarily-polarized nematicons cross as particles, whereas two diffracting ordinary beams interfere.

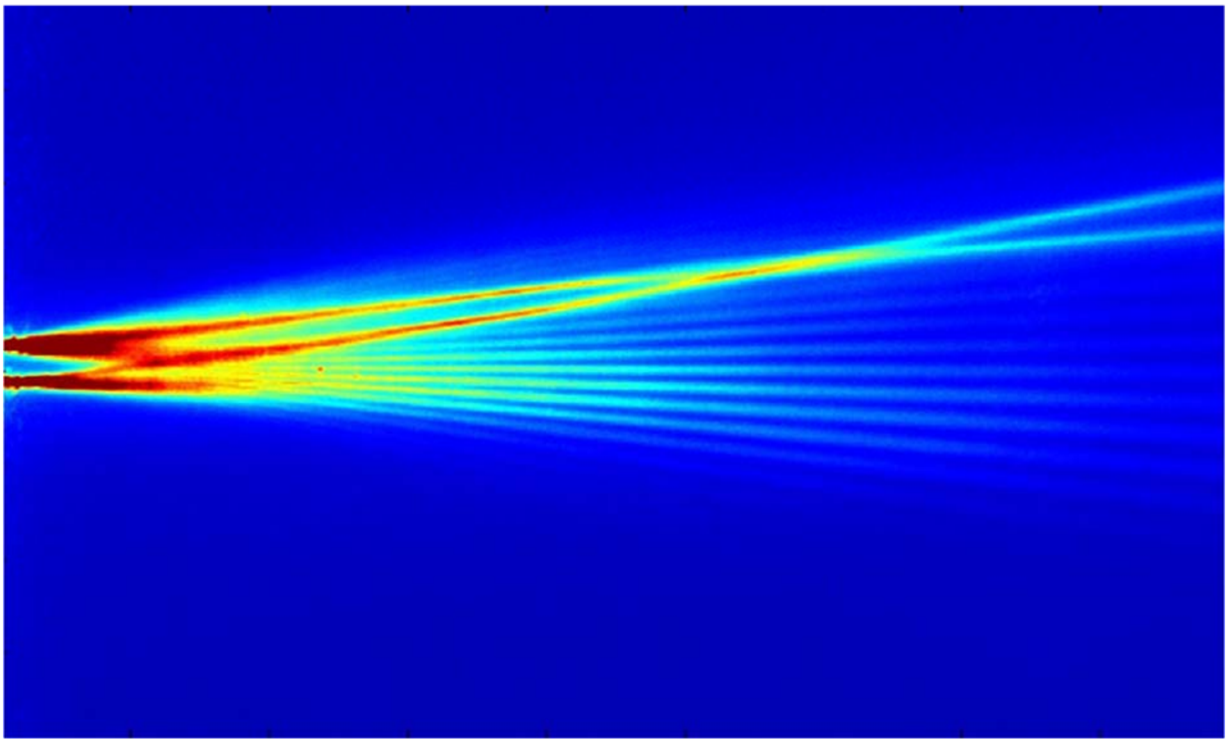

Figure 1. Photographic illustration of the dual wave/particle nature of coherent light beams launched with mixed linear polarizations (ordinary and extraordinary eigenwaves) in a planar cell filled with nematic liquid crystals. Two extraordinary-wave beam components form two walking nematicons which attract, collide and cross. Two ordinary-wave beams diffract and interfere.

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Light-directed structuring of liquid crystals

Etienne Brasselet*

LOMA, CNRS, University of Bordeaux, Talence, France

Liquid crystals are well-known optical materials whose orientation can be controlled by external fields of various nature. In particular, light is well-known for its ability to induce static or dynamic orientational structures, with or without a threshold regarding the optical intensity. The richness of the light-matter interaction when dealing with a soft birefringent makes the various degrees of freedom of light as many parameters to imprint an optical information of a structural nature into liquid crystals. Here we will present recent results illustrating how polarization and spatial degrees of freedom of light can be used for directed optical engineering of elastic distortions in liquid crystals. Two classes of laser-directed structuring will be discussed, namely, the cases of transverse and longitudinal gradient perturbations induced by the light field.

* Author for Correspondence: etienne.brasselet@u-bordeaux.fr

Light with a twist

Morten A. Geday*, Xabier Quintana, Javier Pereiro-García, Pablo de la Rosa, José M. Otón, Manuel Caño-García

CEMDATIC, ETSI Telecomunicación, Universidad Politécnica de Madrid, Av. Complutense 30, 28040 Madrid, Spain

In the past decade bespoke liquid crystal devices have become ever more present in dynamic complex wavefront shaping. This is especially true in the generation of light beams with a helically propagating wavefront also known as an optical vortex. A continuous helical wavefront is characterised by a helical pitch that is an integer number (topological charge, l) of wavelengths (λ), leading to a wavefront that may be described by l intertwined wavefront spirals, each separated by λ in the propagation direction (Figure 1).

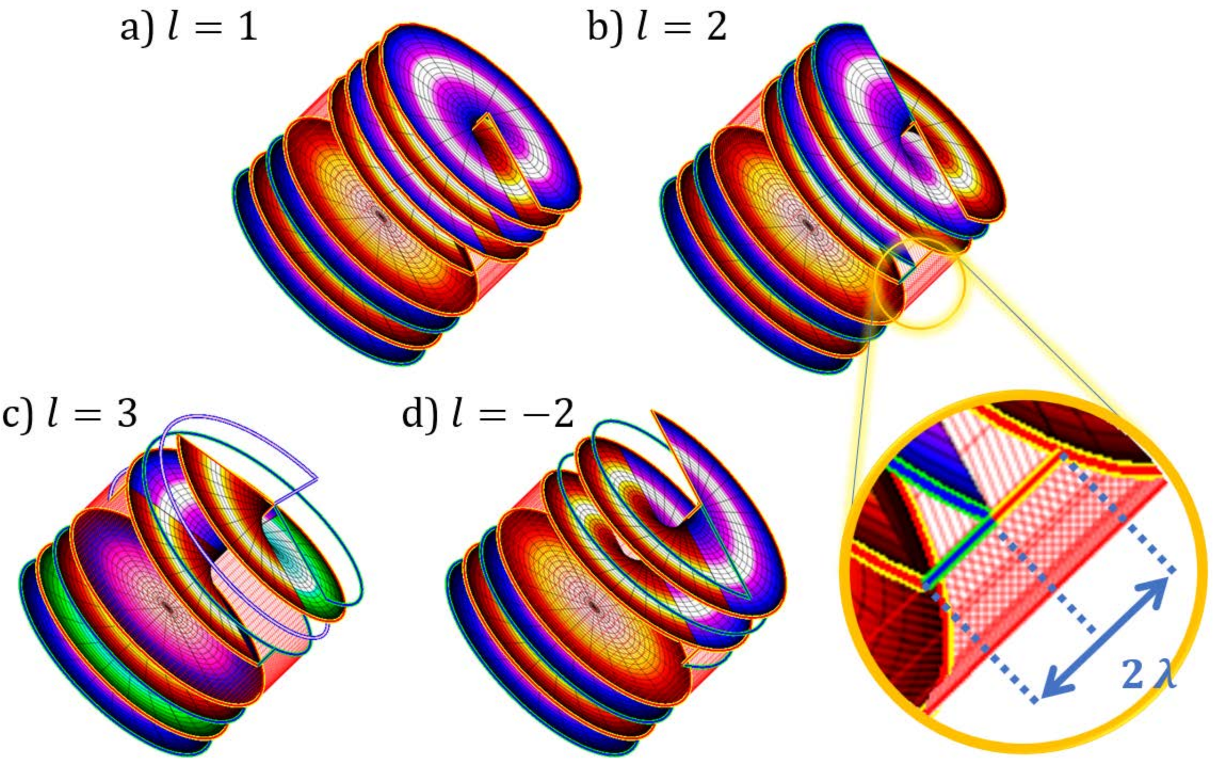

Figure 1. Converting a planar wave into a helically structured vortex beam. Wavefronts with four arbitrary topological charges: l =1, 2, 3 and -2 are presented. Integer topological charges generate continuous intertwined helically propagating wavefronts. In b a single phase-discontinuity of 4 π (2 λ) is introduced, while in c and d multiples phase-discontinuity of 2 π are introduced.

The generation of these optical vortices requires that a relative phase delay is introduced in an azimuthal manner, *i.e.,* the phase delay varies in a clockwise, or anticlockwise sense about the centre of the light beam, opposite to the radial phase variation usually seen in lenses, or in wavefronts expanding from a pinhole or similar. In the literature, l is interchangeably referred to as Topological Charge (*TC*) or as Orbital Angular Momentum (*OAM*).

The conceptually simplest and the most flexible way to introduce the desired optical vortices is to employ linearly polarised light and a spatially varying phase delay employing a conventional nematic liquid crystal. A discrete number of electrodes introduces the specific phase delays in an incident planar propagating wavefront resulting in a discrete approximation to the helical wavefront. The simplest of these is the spiral phase plate, in which the active area is split into a finite number of pie-shaped electrodes.

A conceptually less obvious, and less tuneable method to generate the vortex beams employ liquid crystal based Pancharatnam-Berry (aka Geometric) phase elements, in which the orientation of the slow axis of a homogenously aligned LC is varying spatially in a continuous manner over the active area. A planar wavefront of circularly polarised light may then be converted into helically propagating circularly polarised wavefront. The simplest of these PB phase elements is the q-plate, in which the alignment direction varies in a linear manner with the azimuthal angle about the beam centre.

This presentation will provide an introduction to optical vortex beams, a detailed discussion of how to generate them using liquid crystal devices, and finally an overview of current and near future application of light with twist.

* Corresponding Author: morten.geday@upm.es

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Smectic liquid crystal topological defects, instabilities and their interactions with nanoparticles

Emmanuelle Lacaze
Institut des Nano-Sciences de Paris (INSP),
Centre National de la Recherche Scientifique (CNRS), Paris, France.

We study one-dimensional smectic patterns in order to study smectic topological defects and their interaction with nanoparticles [1]. I will describe recent results brought in the same time by a new methodology of analysis of X-ray data collected at synchrotron facilities and by collaborations with theoreticians. I will show that we now obtain an unprecedented precision in the determination of smectic layer distortion and topological defects present in films of thickness not larger than 300 nm where antagonistic anchorings have been applied at the two interfaces. We not only reveal the intimate structure of smectic topological defects (size and nature), their localization within the smectic film, but we also show how these defects interact with each other to finally stabilize a particularly dense network of defects. Disclinations, dislocations, grain boundaries (chevrons) and topological grain boundaries appear to coexist in the same pattern together with Helfrich-Hurault instabilities. We demonstrate that their presence is mostly induced by the strong bending of the smectic layers close to the curvature centers that also controls the respective evolution of the defects when the thickness of the smectic films varies.

We study the interactions of the smectic defects with nanoparticles, trying to identify how each specific defect interact with nanoparticles [2, 3]. In order to reach this objective, we combine measurements of X-ray diffraction of liquid crystal with and without nanoparticles, of optical microscopy, optical spectroscopy (for metallic nanoparticles) and of fluorescence (for fluorescent nanoparticles). With nanospheres, confinement of nanoparticles in the one-dimensional defects (1D defects: dislocations and disclinations) lead to oriented nanosphere chains as shown by our past studies. We show that the nature of the 1D defect controls the equilibrium distance between nanospheres in the chain [4]. Confinement of nanoparticles in the 1D defects leading to nanosphere chains appears more favorable that confinement in two-dimensional defects (2D defects: topological grain boundaries) leading to nanosphere hexagonal networks [2]. This suggests a larger energy per unit of length for the dislocations and disclinations with respect to the one of topological grain boundaries. Moreover, if confinement in 1D defects obviously leads to oriented nanosphere chains due to the well-defined orientation of our smectic one-dimensional patterns, we would have expected disoriented nanosphere hexagonal networks for confinement in 2D grain boundaries. Our results show that indeed disoriented hexagonal networks form for nanospheres smaller than the defect cores (diameter 3 nm). In contrast, for nanosphere diameter larger than 4 nm, strictly oriented hexagonal networks form. This shows that when the nanosphere diameter is large enough, the nanosphere ligands interact with the oriented smectic layers around the defect core allowing for a guiding of the nanoparticle assemblies by the smectic layers [3]. This allows for an estimation of the grain boundary core of around 4 nm. As a result, in oriented one-dimensional smectic patterns, we control orientation and order of nanoparticle assemblies through the control of nanoparticle concentration and nanoparticle size with respect to the defect cores. This holds for nanospheres and nanorods. For nanorods we show in addition that nanorods remain oriented with their long axes in average parallel to the defects again through the coupling between ligands and oriented smectic layers [3]. Depending on the nanoparticle nature (fluorescent nanoparticles or plasmonic nanoparticles), different kinds of strongly anisotropic optical properties can thus be reached for the composites " one-dimensional smectic pattern with nanoparticles".

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Towards autonomous micromachines powered by active nematics

Claire Doré[1], Z. Liu[1], J. Laurent[1], J. Hardoüin[2], N. Atzin Canas[3], A. Mozaffari[3], R. Zhang[3,4], J. Ignés-Mullol[2], F. Sagués[2], J. de Pablo[3,5], T. Lopez-Leon[1*]

[1] Laboratoire Gulliver, UMR CNRS 7083, ESPCI Paris, PSL Research University, 75005 Paris, France
[2] Departament de Química Física, Universitat de Barcelona, 08028 Barcelona, Spain
[3] Pritzker School of Molecular Engineering, University of Chicago, Chicago, Illinois 60637, USA
[4] Department of Physics, Hong Kong University of Science and Technology, Kowloon, Hong Kong
[5] Center for Molecular Engineering, Argonne National Laboratory, Lemont, Illinois 60439, USA

Active nematics are non-equilibrium fluids composed of anisotropic self-driven units that transform chemical energy into mechanical motion [1]. Distinctive hallmarks of these systems include their spontaneous self-organization into collective states in which oriented fields are coupled to velocity, as well as their capability to adapt to the environments where they reside [2-4]. Recent theoretical and numerical works have shown the potential of these active fluids to control information transport in channel networks [5,6]. These works have laid conceptual foundations for the development of autonomous microfluidic micromachines with unprecedented functionalities, including circuits capable to perform universal logical operations through the synchronized self-organization of many individual network channels.

Here, we implement these ideas experimentally, using a two-dimensional microtubule-kinesin active nematic, formed by spontaneous self-assembly at an oil-water interface. To confine the active nematic, we design 3D-printed microfluidic devices, where the channels are holes in a polymeric platform, which we place at the interface where the active nematic form. We investigate how the local geometry of the channels and the global topology of the network impact the emerging flows. We observe spontaneous directional flow in elementary channels with open ends, where the flow direction can be selected by shaping the channel wall with a ratchet pattern. At bifurcations, the interplay between activity and flow conservation frustrates the simultaneous presence of flow along the three connected channels: flow states tend to be polarized, preferentially opting for the longest path, in agreement with theoretical predictions. However, we show that the geometry of the bifurcation, not considered in previous models, plays a crucial role in the flow distribution through the network. Finally, we show the AND/OR logical circuit can be implemented by combining elementary channels and bifurcations, in which bits of information are encoded via the presence (1) or absence (0) of flows at the network inlets/outlets. These experiments shed light on the design principles guiding the conception of functional autonomous microfluidic networks based on active nematics.

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* Author for Correspondence: teresa.lopez-leon@espci.fr

Active and driven nematic topological defects

Miha Ravnik[1,2*]

[1]Faculty of Mathematics and Physics, University of Ljubljana, Jadranska 19, 1000 Ljubljana, Slovenia
[2] J. Stefan Institute, Jamova 39, 1000 Ljubljana, Slovenia

Nematic fluids are characterised by internal orientational order, which upon tuning or frustration, can exhibit topological defects. In active or driven nematics, topological defects emerge as dynamic objects that exhibit complex regular or irregular dynamics. Here, we give an overview of dynamic structures of topological defects in three-dimensional active and driven nematics. Specifically, we show defect profiles in three-dimensional active turbulence, under confinement and in bulk. We discuss the nature of three-dimensional defect loops and their changing local winding number structure. We show refinement and coarsening upon changing the activity and present continuous generation of topological defects in a passively driven nematic.

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* Author for Correspondence: miha.ravnik@fmf.uni-lj.si

Automated Flow Synthesis of Algorithmically Designed Ferroelectric Nematogens.

Richard J. Mandle[1,2]

[1] School of Physics and Astronomy, University of Leeds, UK, LS2 9JT
[2] School of Chemistry, University of Leeds, UK, LS2 9HT

* r.mandle@leeds.ac.uk

Polar molecules are ubiquitous in our daily lives (e.g. water), possessing regions of positive and negative charges that generate a permanent electric dipole moment. While these dipoles are usually randomly oriented and cancel out in condensed phases, the ferroelectric nematic phase (N_F) is an exception; the constituent molecular dipoles align parallel to each other, resulting in a bulk material that is polar. [1-6] The N_F phase exhibits exceptional properties that render it the most attractive candidate for various emerging applications including sensors and actuators. However, the development of new N_F materials with tunable properties remains a challenge due to the limited knowledge of the structure-activity relationship.

In this talk, I will discuss recent advances in the synthesis of N_F materials using continuous flow chemistry, which greatly increases the number of materials that can be prepared in a given time. I will also introduce algorithmic approaches to designing and ranking new candidate N_F materials, followed by automated synthesis using a platform that streamlines the process. Furthermore, I will highlight the importance of atomistic simulations in predicting the incidence of the N_F phase in various materials and illuminating the electrostatic interactions that drive its formation. These efforts pave the way for the development of novel N_F materials with tailored properties that could revolutionize various fields.

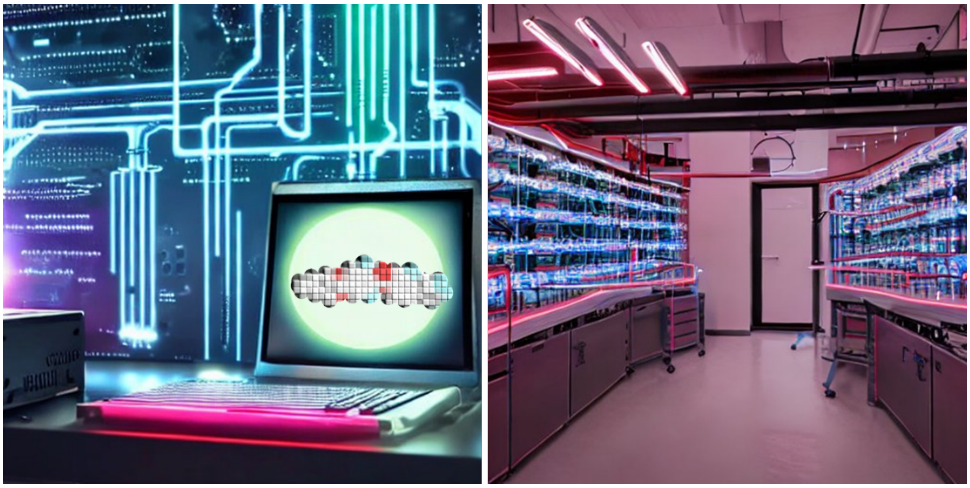

Fig. 1: A text-to-image AI interpretation of “a molecule being designed by a powerful computer” (left) and “an advanced flow-chemistry laboratory with glowing microfluidic tubes” (right)

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Stimuli-responsive Hydrogen-Bonded Liquid Crystalline Elastomers

Albert P.H.J. Schenning*, Dirk Jan Mulder, Sean Lugger

Laboratory of Stimuli-responsive Functional Materials and Devices (SFD), Department of Chemistry and Chemical Engineering, Eindhoven University of Technology, 5600 MB, Eindhoven, The Netherlands

Hydrogen-bonded liquid crystalline elastomers have emerged as "smart" materials with stimuli-responsive, self-healing, and recyclable properties [1]. The liquid crystalline self-organization gives the materials their unique responsive nanostructures. These materials can be used for programmable soft actuators using segmented liquid crystalline polythiourethanes. The dynamic structural character of the hydrogen bond crosslinks can be used to construct self-healing and recyclable actuators.

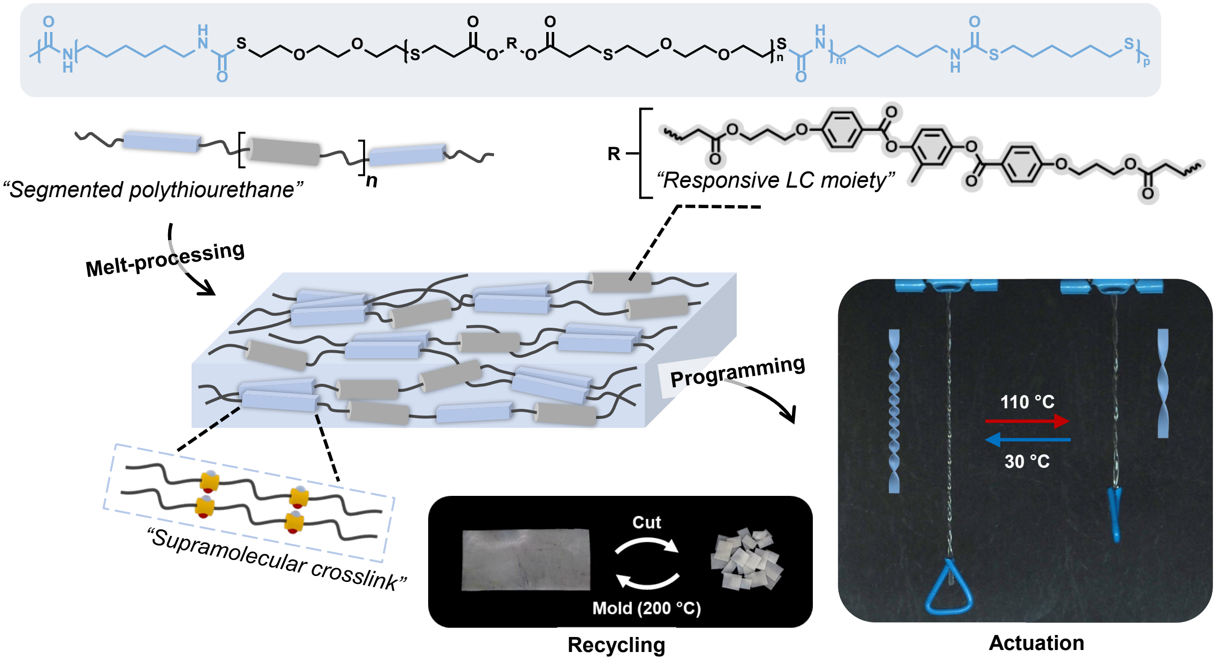

Figure 1. Responsive, recyclable hydrogen-bonded liquid crystal elastomers [2].

In this lecture, our recent findings on responsive hydrogen-bonded thiourethane liquid crystal elastomers will be presented and discussed [2].

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* Author for Correspondence: a.p.h.j.schenning@tue.nl

Topological photonics with liquid crystal microcavities: control over the spin-orbit coupling of light

Jacek Szczytko

Institute of Experimental Physics, Faculty of Physics, University of Warsaw, Poland

Topological photonics carries a key promise for the development of integrated optical circuits – otherwise photons being uncharged cannot have their flow oriented by an electric field. We have invented a method to control electrically spin-orbit coupling (SOC) of light using specially designed photonic structures - birefringent microcavities: liquid crystal layer enclosed between two parallel distributed Bragg reflectors (Fig. **a**). In solid-state systems with broken inversion symmetry, SOC leads to the so-called Dresselhaus and Bychkov-Rashba SOC Hamiltonians, which are of particular interest in the context of spintronics, topological insulators, and superconductors. However, SOC in solid-state matter cannot be easily controlled and modified. Birefringent optical cavities allow for a wide range of tunability of photonic modes. It led to the observation of an optical analogue of the spin Hall effect and the realization of artificial gauge fields for parameters that range far beyond those previously considered experimentally and theoretically [1]. Spin patterns, corresponding to the second-order merons and anitimerons known as (half)skyrmions in magnetism, were realized [2].

In particular, if two photonic modes of orthogonal polarization and different parity are tuned to the resonance, a characteristic scheme of spin-polarized dispersion of Rashba-Dresselhaus (RD) SOC is formed [3] (Fig. **b**). Spin coherence between such modes gives rise to long-range polarization texture, so-called an optical persistent spin-helix – the long-range polarization (or pseudo-spin) textures of the in-plane traveling photons [4] (Fig. **c**). By dispersing a molecular dye in a liquid-crystal microcavity we introduced an optical gain (Fig. **d**). We created an inseparable state between the valley and polarization degrees of freedom of cavity photons demonstrated as an optical persistent spin helix lasing [5] (Fig. **e**), and strong light-matter coupling in RD SOC of exciton plaritons in perovskites [6].

The platform we proposed opens new possibilities in topological photonics [7,8]. In addition to the standard approach based on lithographic methods, in the case of liquid crystal cavities, it is possible to create self-organizing macro-molecular structures (Fig. **f**) and control their sizes and shapes by temperature or electric field (Fig. **g**).

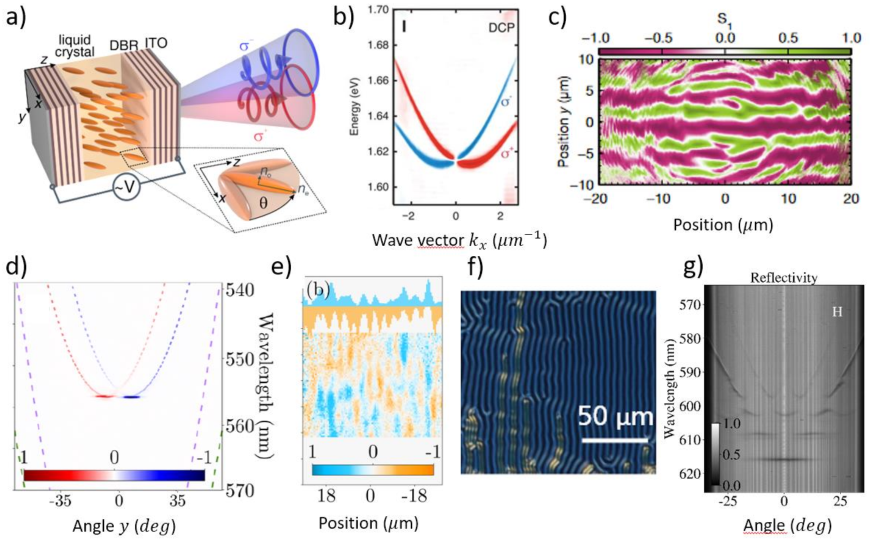

FIGURE
a) scheme of liquid crystal microcavity [1-7];
b) reflectivity showing Rashba-Dresselhaus (RD) SOC of light [3];
c) optical persistent spin helix (experiment) [4];
d) lasing in RD spin-orbit regime [5];
e) persistent spin-helix on the surface of RD laser [5];
f) Uniform Lying Helix (ULH, self-organizing LC structure);
g) dispersion relation of ULH in a microcavity

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Author for Correspondence: Jacek.Szczytko@fuw.edu.pl

Metallomesogens from design to functional properties

Elisabeta I. Szerb

”Coriolan Drăgulescu” Institute of Chemistry, Romanian Academy, 24 Mihai Viteazu Bvd., Timişoara 300223, Romania

Metallomesogens are multifunctional materials with properties resultant from the synergistic/cooperative combination of the properties derived from the coordination complex like photo- or electro-luminescence, magnetic, catalytic and so on, and the ordered fluid supramolecular architectured phase properties (Figure 1) [1,2]. Therefore, may be considered highly valuable candidates for practical applications in a wide range of fields, from optoelectronics to energy, environment and biomedicine.

The initial huge optimism in obtaining functional metallomesogens for practical applications diminished due to their drawbacks (high transition temperatures, decomposition during heating and high mesophase viscosities). A proper molecular engineering allows nowadays the design and synthesis of room temperature metallomesogens, while the possibility of widening their potential applicative window tackling important global challenges in health, environment, climate and energy should re-enforce their importance.

Herein, the design of a class of metallomesogens based on bioavailable zinc and copper metal centers, decorated with N-donor functionalized ligands and non-innocent counterions will be presented. The relationship molecular structure-supramolecular structure-functional properties is followed, and some important achievements highlighted: i) the first polarized fluorescence of an oriented film of a Zn(II) columnar metallomesogen [3]; ii) the rational design of ordered fluid metallomesogens based on homo or hetero-metallic coordination complexes with a controlled distribution of metal centers used as modifiers of carbon-based materials for *in-situ* generation of ordered metal oxide nanoelectrode arrays for the fabrication of electrochemical high performance hybrid sensors [4].

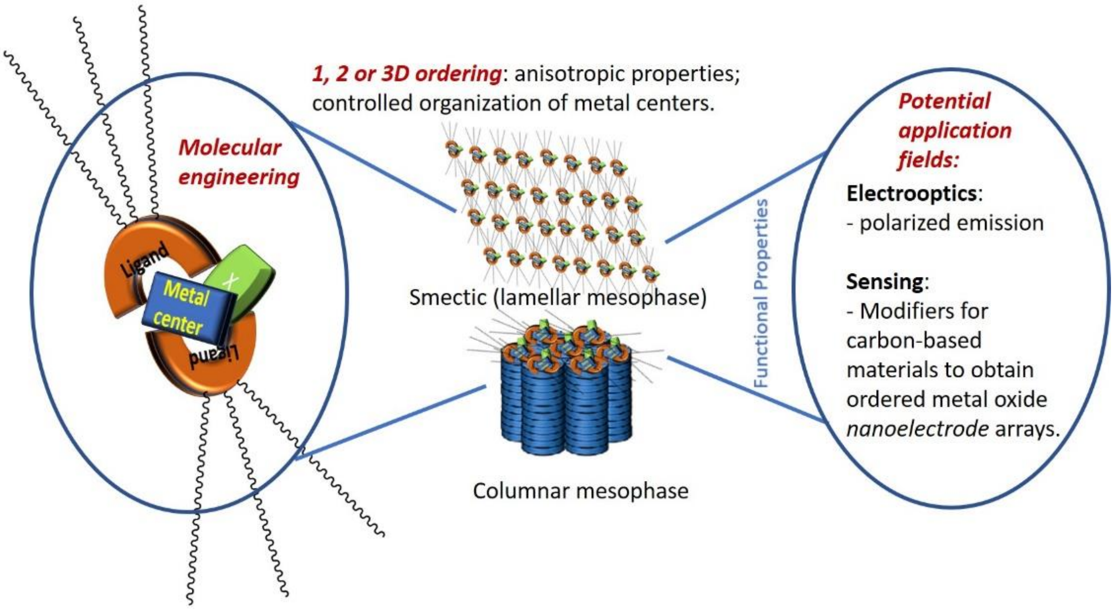

Figure 1

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* Author for Correspondence: eszerb@acad-icht.tm.edu.ro

Invited Speakers

Electric field guiding and polarization switching in microchannel-confined ferroelectric nematics

Tommaso Bellini

Dept. of Medical Biotechnology, University of Milano, Milano 20129, Italy

The combination of large spontaneous polarization and fluidity makes the ferroelectric nematic liquid crystalline phase (NF) responsive to electric fields in ways that have no counterpart in other materials. One key property of this material is its capacity to promptly accumulate, by miniscule collective orientations, large quantities of bulk and surface charge. This extreme electric susceptibility underpins a form of electric field screening that is distinctive of the NF phase, with no analogous in other non-conductive fluids. We show that, because of this property, the NF phase is capable of guiding of the electric field along complex paths.

We confined the liquid crystal RM734 in microchannels that connect electrodes through straight and curved paths, some of which multiply connected. We find that by applying d.c. electric fields as low as 0.5 V/mm, the NF phase orders with its polarization **P** smoothly following the winding paths of the channels even when they are oriented perpendicularly or opposite to the line connecting positive to negative electrodes. By analyzing the complex multistage switching process which follows the reversal of E, we showed that the electric field **E** is uniform and oriented along the channel.

Polarization following, electric field guiding and multistage polarization switching dynamics are also found in numerical simulations of a quasi-2D continuum model of NF liquid crystals in microchannels.

Analogous studies in microchannels with multiply connected geometries enable observing oscillatory, frustrated and defected NF ordering, revealing additional features of this phase.

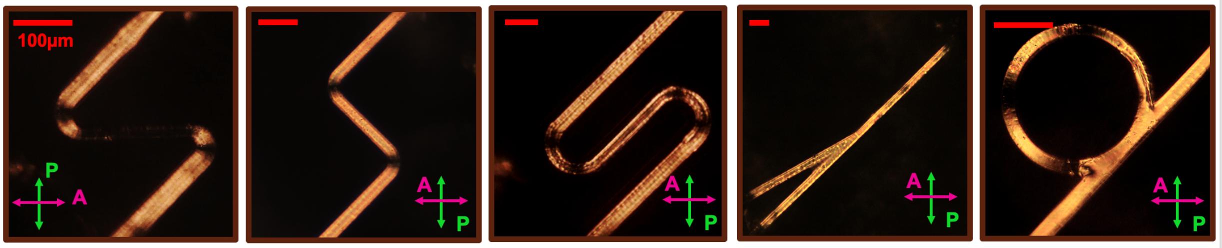

Figure 1. Polarized transmission optical microscopy images of microchannels filled with RM734 in the NF phase. The channels are about 1 mm long and terminate in electrodes providing a voltage of 0.5 V.

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* tommaso.bellini@unimi.it

Dynamic Complex Liquid Crystal Emulsions

Alberto Concellón[1*]

[1]Instituto de Nanociencia y Materiales de Aragón (INMA), CSIC-Universidad de Zaragoza,
C/Pedro Cerbuna 12, 50009 Zaragoza, Spain

Complex emulsions are of increasing importance for applications in pharmaceuticals, medical diagnostics, or chemical sensing [1]. We have recently introduced liquid crystals (LCs) into complex emulsions and demonstrated how the anisotropic nature of LCs provides new functionalities and unusual behaviors [2,3]. For instance, droplet morphology can be dynamically switched between LC-in-fluorocarbon-in-water double emulsions (LC/F/W), Janus emulsions, and inverted double emulsions (fluorocarbon-in-LC-in-water, F/LC/W) in response to changes in the surrounding surfactants. The presence of two LC interfaces (i.e., LC/W and LC/F) also provides additional topological constrains on mesogens organization and affects defects configuration. Nonetheless, by using appropriately designed surfactants that control the LC director field at each interface, we can prepare droplets with different internal configurations, in which mesogens arrange in the directions dictated by the mesogenic surfactants. This strategy also enables the controlled creation of topological singularities with chemical functionality for the precise attachment of biomolecules or nanoparticles (NPs) at the droplets' interface. In fact, this topological defect-driven functionalization can be employed as a powerful and straightforward strategy for magnetic NPs assembly at interfaces, wherein the confined NPs can tune the LC ordering by applying an external magnetic field [4].

The ability to achieve precise organization of recognition sites at interfaces also provides access to a variety of sensing applications, in which the LC alignment acts as an amplifier for local perturbations that occur at the LC/W interface. Nonetheless, in these sensing systems the observables (i.e., LC ordering transitions) typically require optical microscopies with crossed polarizers, which avoids analyte quantification and limits their real-world utility. To improve the simplicity of the read-out of ordering transitions, we have introduced multichomophore systems within LC droplets that produce emissive signals for the quantitative detection of pathogenic species without the need of complex and specialized equipment. The simple to fabricate complex LC emulsions and the facile optical read-out provide a new approach for biological and chemical sensing. A diversity of biosensors based on LC emulsions are envisioned for the future.

Acknowledgement
I am grateful for the support from the "Ramón y Cajal Program" (Grant No. RYC2021-031154-I) funded by MCIN/AEI/10.13039/501100011033 and EU-"NextGenerationEU"/PRTR.

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* Author for Correspondence: aconcellon@unizar.es

Shaping nematic droplets with surface tension

K. Peddireddy[1], S. Čopar[2], K.V. Lee[3], I. Muševič[24], C. Bahr[1] and V.S.R. Jampani[4]

[1]Max Planck Institute for Dynamics and Self-Organization, Göttingen, Germany
[2]Faculty of Mathematics and Physics, University of Ljubljana, Ljubljana, Slovenia
[3]Tokyo University of Science, Tokyo, Japan
[4]Jožef Stefan Institute, Ljubljana, Slovenia

Shaping liquids is a difficult task, as the flowing nature combined with surface tension tend to force the liquids into a round shape. In liquid crystals, anisotropy of the bulk material and the corresponding elastic response can induce deviation from the spherical shape, forming tactoids and generalized elliptical shapes. Electric fields can be used to further stretch and deform the resulting drops. However, as long as the surface tension dominates, the shapes will not deviate much from a spherical droplet.

I will present a system, where a combination of two surfactants – one dispersed in the aqueous host liquid, and the other in the nematic LC droplet – is used to achieve vanishing and effectively even negative surface tension. This allows for the surface of the droplet to grow freely, and the bulk elasticity is instead limiting emulsification and shaping the droplets [1].

In the nematic phase, multiple fibers of a consistent thickness start growing out of an initial droplet upon cooling. The molecular orientation at the interface is forced to be perpendicular, which induces radial configuration in a droplet and escaped radial structure in a fiber. A theoretical model can be constructed that describes the equilibrium shape of the droplet-fiber construct, and predicts its dimensions. If the system is cooled even further into the smectic phase, the fiber breaks up into a string of monodisperse droplets.

The same mechanism of forcing growth of the interface surface area can be shown to produce different results based on the phase of the liquid crystal – e.g. smectic, chiral smectic, or chiral nematic. Thus we can manipulate liquids to grow slowly and reversibly into shapes that lend themselves into further manipulation, which can be a stepping stone for further advancements in soft matter engineering.

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* Author for Correspondence: simon.copar@fmf.uni-lj.si

Photo-thermal Controlled Optical Absorber based on Liquid Crystal Metasurfaces

Francesca Petronella[1], Tristan Madeleine[2], Vincenzo De Mei[3], Federica Zaccagnini[3], Marinella Striccoli[4], Gianpaolo D'Alessandro[2], NelsonTabiryan[5], Mariacristina Rumi[6], Timothy J. Bunning[6], Jonathan Slagle[6], Malgosia Kaczmarek[2], and Luciano De Sio[3,7*]

[1]National Research Council of Italy, Institute of Crystallography, CNR-IC, Rome Division, Area della Ricerca Roma 1 Strada Provinciale 35d, n. 9 - 00010 Montelibretti (RM)

[2]School of Mathematical Science, School of Physics and Astronomy, University of Southampton, Southampton SO17 1BJ, United Kingdom
[3]Department of Medico-Surgical Sciences and Biotechnologies Sapienza University of Rome, Latina, Italy
[4]National Research Council of Italy, Institute of Chemical and Physical Processes, CNR-IPCF Bari Division, Via Orabona 4, 70126 Bari, Italy
[5]Beam Engineering for Advanced Measurements Company, Orlando, Florida 32810, USA
[6]Materials and Manufacturing Directorate, Air Force Research Laboratory, Wright-Patterson Air Force Base, Ohio 45433-7707, USA
[7]National Research Council of Italy, Licryl, Institute NANOTEC, Arcavacata di Rende, Italy

Liquid crystals (LCs) based optical components enable the active control of the light property thanks to the opportunity to apply external stimuli (e.g., electric/magnetic fields, temperature variations, optical fields, etc.).[1] This exciting possibility has pushed LCs to the forefront of several research fields ranging from displays [2] to biosensing [3] applications. Because of the booming of light communications, there is a constant need for new materials and optical devices with superior optical performances. Metasurfaces are innovative optical devices made of properly engineered surfaces with a thickness smaller than the wavelength of the incident light. A perfect absorber metasurface can be realized by adequately organizing subwavelength elements (e.g., plasmonic nanoparticles) on a reflective surface, covered with a dielectric layer, resulting in an array of resonators that collectively act to achieve complete absorption of the resulting resonant wavelength.[4] Unfortunately, despite the excellent optical properties of metasurfaces, they lack tunability and cannot compete with conventional LC-based optical components. To boost the utilization of metasurfaces to realize a new generation of dynamically controlled optical components, we report our recent finding based on the powerful combination of an innovative metasurface-perfect absorber and LCs. Silver nanocubes (Ag NCs, side length of 100 nm) are self-assembled and immobilized on a 50 nm thick gold layer (deposited by sputtering on a 1 cm^2 glass substrate) using a polyelectrolyte multilayer as a dielectric spacer.

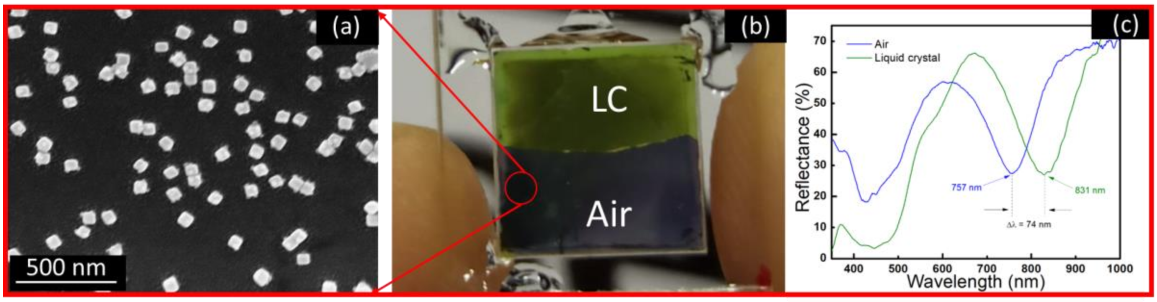

Figure 1. Scanning electron microscope micrograph (a) of the sample (b) partially infiltrated with LC. Diffuse reflectance spectroscopic measurements of the sample (c) without (blue curve) and with (green curve) LC.

The resulting optical absorbers show a well-defined reflection band centered in the near-infrared of the electromagnetic spectrum (700-750 nm), a very high absorption efficiency (≥ 60%) at the resonant wavelength, and an elevated photo-thermal efficiency. The metasurface-based optical absorber combined with a nematic LC (NLC, 6CHBT) layer, planarly aligned via a photo-aligned (PAAD-72, by BEAMCo) top cover glass substrate, shows homogeneous NLC alignment and a photo-thermal tunable absorption band of about 30 nm. Detailed thermographic studies and spectroscopic investigations highlight the extraordinary capability of the active metasurface-based absorber to be utilized as a controllable light attenuator.

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* Author for Correspondence: luciano.desio@uniroma1.it

Polarity effects in ferroelectric nematics and their hybrids in bulk and confinement

Alexey Eremin[1*]

[1]Department of Nonlinear Phenomena, Inst. of Physics, Otto von Guericke University, Universitätsplatz 2, 39106 Magdeburg, Germany

Recently discovered ferroelectric nematics are true 3D ferroelectric fluids whose existence was theoretically contemplated more than a hundred years ago. Such ferroelectric/ferroelastic materials are distinguished for their remarkable properties, such as large electric susceptibility, pyroelectric, and second-order nonlinear optical coefficients [1]. In this presentation, we explore the effects of polarity on the mechanical properties and fibre-forming behaviour in the room-temperature ferroelectric nematic phase (N_F) [2, 3]. With various techniques such as SHG microscopy, magneto- and electro-optical studies, we characterise the polar order and determine the elastic constants in a wide range of temperatures in pure materials and N_F/nanoparticle hybrids. We show that softening of the splay elasticity in the high-temperature non-polar nematic phase turns to the splay-stiffening in the ferroelectric nematic, which can be attributed to the electrostatic avoidance of the polarisation splay.

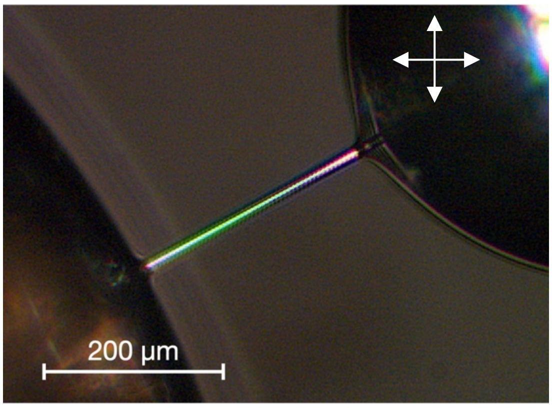

Figure 1: A filament drawn in the N_F phase at 26°C and observed in polarised light.

We also demonstrate the formation of metastable liquid filaments in N_F. In compounds with multiple nematic phases, we show that only N_F phase can form birefringent filaments with the slenderness ratio exceeding the Rayleigh limit of π. The filaments exhibit remarkable nonlinear optical properties, which allow us to establish the character of the polar order within them. Additionally, the high polarity of the N_F phase gives rise to peculiar behaviour in external electric fields allowing the bridges to form through electric instabilities of droplets in vertical electric fields. We discuss the role of polarity and spontaneous splay of polarisation on the stability of the N_F bridges and filaments.

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* Author for Correspondence: alexey.eremin@ovgu.de

Anomalous Diffusion Approach to Electrical Impedance Response of Liquid Crystals

Luiz Roberto Evangelista et alii.[1,2,3]*

[1]PFI-UEM, Universidade Estadual de Maringá, Maringá, 87020-900, Paraná, Brazil.
[2]UTFPR—Campus de Apucarana, Apucarana, 86812-460, Paraná, Brazil.
[3]Physics Department, University of Calabria, Rende 87036, CS, Italy.

The impedance spectroscopy technique – in which an oscillating electric field at different frequencies is applied to the sample – is a remarkable way of accessing diffusion behavior [1]. The impedance response depends on ionic motion (diffusion and drift current) and other physical parameters of the material, and it is a powerful experimental technique, relatively simple to use, non-destructive, and responsible for providing information about ionic movement, adsorption and desorption, viscosity, molecular polarization, conductivity, morphological characterization, and growth dynamics [2]. A robust approach to interpret such data is the Poisson-Nernst-Planck (PNP) model and its variations or extension – PNPA, for example (the letter "A' standing for anomalous), where impedance response must simultaneously satisfy the fractional diffusion equations for positive and negative ions and the Poisson's equation. It is thus more reliable than the simple Warburg diffusion model, since from the measured spectra one can obtain valuable information such as dielectric constants, Debye length, number of ions, diffusion coefficient and many others.

In this work, we discuss recent results and points to potential uses of the impedance spectroscopy technique connected to a PNPA model to study ionic diffusion in cholesteric and modulated liquid crystal materials as a way of characterizing not only the physical parameters of the material (which is surprisingly scarce within this framework for such materials), but also to understand how the natural modulation present in the media affects ionic diffusion [3]. The model uses fractional derivatives to measure diffusivity rather than looking directly to the behavior of conductivity at low frequencies. Furthermore, it is possible to look not only for micro-scale (nanometer) modulations but rather to mesoscale (micrometer) modulations, as this is the typical length scale of many biological materials.

Hence, we investigate the impedance spectroscopy of nematic, cholesterics and other modulated phases of liquid crystals (like the twist-bend ones) in the framework of the PNPA model and anomalous diffusion behavior [4], aiming to characterize the physical parameters and diffusivity from the conductivity at low-frequency regimes.

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* Author for Correspondence: lrevang@gmail.com

Cellulose-based nanocomposites for anti-counterfeiting applications

Erica Fuoco[1,2], Pedro E. S. Silva[3], Ricardo Chagas[3], Joana S. Rodrigues[3], Jorge M. Pereira[3], Maria P. De Santo [1,2], Riccardo C. Barberi[1,2], Maria H. Godinho[3], and Susete Nogueira Fernandes[3,*]

[1]Physics Department, University of Calabria, Rende 87036, CS, Italy
[2]CNR-Nanotec c/o Department of Physics, University of Calabria, Ponte P. Bucci, Cubo 33B, 87036 Rende Cosenza, Italy
[3] i3N/CENIMAT, Department of Materials Science, School of Science and Technology, NOVA University Lisbon, Campus de Caparica, Caparica, Portugal

Counterfeiting is currently the second-largest source of organized crime, disturbing all segments of society (documents, clothing, food, automotive parts, pharmaceuticals, and even electronics), reaching industry, government, and the end-users. Counterfeit products have become more accurate with technology development, and deterrent anti-counterfeiting solutions are in constant demand. Structural-colour-generating films from cellulose nanocrystals (CNC), nanocomposites present good properties to be used as anti-counterfeiting systems. Derived from liquid crystalline lyotropic suspensions, these photonic materials present selective left-handed circular reflection, which can be used as a covert anti-counterfeiting feature, the structural colouration that can act as an overt feature, flexibility, and response to multiple stimuli (such as relative humidity, electric field, temperature, and polar solvents) as additional covert features. [1-3] Tunning optical properties and flexibility of solid films of CNC with other cellulosic derivatives was explored by the addition of hydroxypropylcellulose (HPC) [3] and hydroxypropylmethylcellulose (HPMC) [4] in home-made and commercial cellulose nanocrystals in liquid crystalline colloidal suspension, within the biphasic regime. HPC content allows modulating the reflected pitch value within all composite systems and induces flexibility, while HPMC gives rise to a more elaborate optical response, highly dependent on the origin of the CNC and molecular weight of the HPMC, with left-handed and apparent right-handed optical light reflection. These new photonic cellulose-based nanomaterials are excellent candidates as anti-counterfeiting optical variable devices.

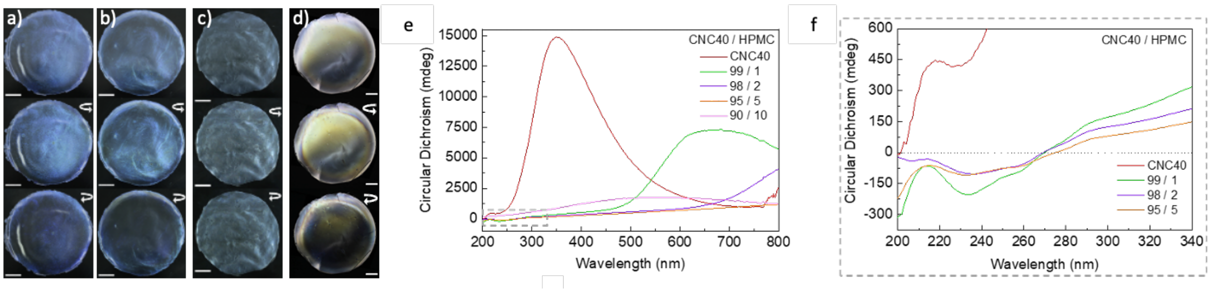

Figure 1. CNC/HPMC Photonic Systems of a-c) commercial CNC, d) home-made CNC; HPMC/CNC ratio a) 1, b) 2, c) 30 wt.%, d) 30%wt HPC with home-made CNC. e-f) Circular dichroism spectra of samples with different content of HPMC

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* Author for Correspondence: sm.fernandes@fct.unl.pt

Multiphase DNA based liquid - liquid crystalline phase separated systems

Tommaso P. Fraccia[1,2*], Ajay Verma[2], Damien Cuvelier[3] and Nicolas Martin[4]

[1]DiSFeB, University of Milano, Milano 20133, MI, Italy
[2]UMR8231, ESPCI Paris, PSL Research University, Paris 75005, France
[3]Instituit Curie, UMR144, Paris 75005, France
[4]CRPP, UMR5031, University Bordeaux, CNRS, Pessac, France

It's well established the fact that concentrated aqueous solutions of double-stranded DNA (dsDNA) oligomers can display lyotropic liquid crystal (LC) phases driven by hierarchical self-assembly and chromonic stacking. Coacervates are a class of associative liquid-liquid phase separated systems which occur in solutions of oppositely charged polyelectrolytes and play important roles as membraneless compartments in living cells.

Here we report the simultaneous appearance of coacervation and LC ordering in mixtures of dsDNA and cationic poly-Lysine peptides, leading to liquid-liquid crystalline phase separations (LLCPS), that produce dense DNA/polycations rich LC microdroplets in coexistence with a diluted isotropic phase. Diverse LC phases, including N^*, C_u and C_2, formed as function of polyelectrolytes concentration, charge ratio, temperature and monovalent salt concentration [1]. Secondly, in mixtures of DNA and azobenzene trimethylammonium bromide (azoTAB) cation, light-responsive assembly and disassembly of columnar LC coacervates, induced by azobenzene trans/cis photo-isomerization in blue/UV light, is exploited to control chemical ligation reactions of DNA oligomers [2].

Lastly, the combination of two DNA species differing in structure, length or end-to-end interaction, has been recently shown to trigger a second ISO-LC phase separation inside the dense coacervate phase, producing what we named multiphase liquid-liquid crystalline coacervates [3]. Here ISO-ISO, ISO-N* and ISO-Cu coexistence are consistent with the spontaneous segregation based on flexibility, between rigid duplexes and flexible single-strands, or based on the degree of aggregation, in polydisperse LC-forming/LC-non-forming dsDNA systems. For I-N* coexistence the difference in surface tension of the different phases causes the arrangement of multiphase liquid-liquid crystalline coacervates in the form of Janus and patchy droplets in which DNA molecules are spatially organized based on their structural properties (Figure 1). By increasing temperature N* phase melting followed by multi-phase to single-phase transition is observed. Conversely the I-N* coexistence is restored upon cooling.

The reported features of LLCPS open promising compartmentalization strategies not only to realize advanced biomaterials, but also with potential relevance for prebiotic chemistry, synthetic biology and drug delivery [4].

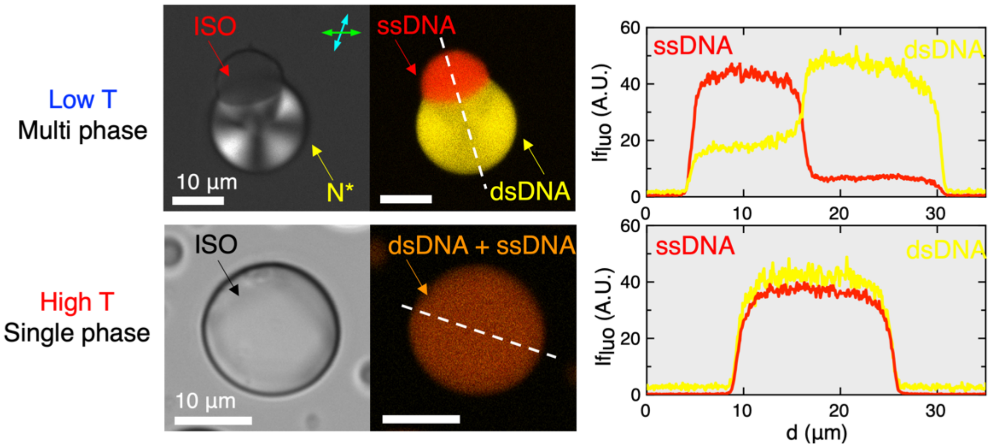

Figure 1. Polarized light and fluorescence confocal micrographs of charge balanced dsDNA/ssDNA/Poly-L-Lysine mixtures exhibiting multiphase ISO-N* Janus droplets at room temperature, in which dsDNA and ssDNA are segregated in the N* and I phase, respectively. T increase causes N* melting and transition to single phase droplets.

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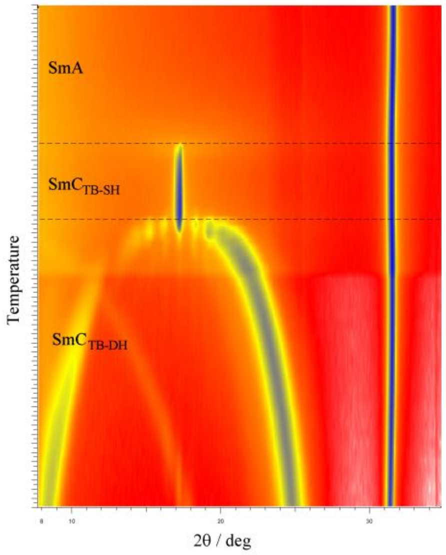
* Author for Correspondence: tommaso.fraccia@unimi.it

Complex twist bend smectic phases

Ewa Gorecka

Faculty of Chemistry, University of Warsaw, Zwirki i Wigury 101, 02-089 Warsaw, Poland

Interestingly, some systems can be chiral only due to helicity, despite the lack of stereogenic centers in the molecules forming the helix. In such systems, a spontaneous process of symmetry breaking occurs, leading to the formation of domains with opposite chirality. One striking example of a helical structure made of achiral molecules are twist bend (TB) liquid crystal phases. In addition to the twist-bend nematic phase, many smectic phases have recently been discovered. They can have a simple helical structure, analogous to the SmCα phase, built of bi-layers, analogous of the $\mathrm{SmC_A}$ helical structure, or even more complex. Of particular interest are analogs of the SmCFi2 phase, with phase transitions from a commensurate four-layer helix to an incommensurate four-layer helix. Several structural modes found in dimeric or rigid bent core molecules will be presented. We also study the influence of chiral doping on the twist-bend phase structure. The helical structure was studied by resonant x-ray diffraction method, and general aspects of application of this method for resolving structure of various complex liquid crystalline structures will be discussed.



Evolution of resonant x-ray signals across the phase transition from commensurate four-layer helix ($\mathrm{SmC_{TB-SH}}$) to incommensurate four-layer (($\mathrm{SmC_{TB-DH}}$) helical structure.

* Author for Correspondence: gorecka@chem.uw.edu.pl

Bacterial micro-swimmers in colloidal liquid crystals

Henri Truong[1], Lachlan Alexander[1], and Eric Grelet[1*]

[1]Université de Bordeaux, CNRS, Centre de Recherche Paul-Pascal,
115 Avenue du Dr Schweitzer, 33600 Pessac, France

Active matter are systems whose constituents are able to harvest energy from their environment to generate self-propelled motion. Such out-of-equilibrium systems exist in the Nature at different scale ranging from macroscopic (bird flocks, school of fish …) to microscopic (bacteria, spermatozoa …) scale. Motion of bacteria in a complex fluid is a common occurrence in life and happens, for example, when they are moving through the human body for its infection. Although it is a common occurrence, little is known about the dynamics of such active particles in complex fluids.

To tackle this problem, we have been studying the swimming of the bacteria Bacillius Subtilis in a complex fluid of colloidal liquid crystal through optical microscopy and single particle tracking. The liquid crystalline phase used in our work is formed by suspensions of fd viruses, widely used for many years in soft matter as a model system of rod-like particle [1].

In addition to the visualization of the bacteria body, our experimental system allows us to have a direct observation of every key component labelled with “orthogonal” fluorescent dyes: bacteria flagella which generate the motion, as well as the viral rod-shaped colloids. Single particle tracking of the micro-swimmers allows to determine both the velocity and the wobbling motion of the bacteria in presence of colloidal particles.

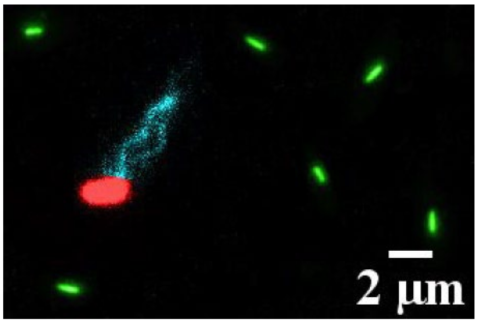


Figure 1. B. Subtilis bacterium and fd viruses observed by fluorescence microscopy.

Recent work done on bacteria with molecular liquid crystal has shown the possibility to monitor the swimming direction [2] thanks to the liquid crystal orientation. We will address this question in the case of colloidal liquid crystal, and we will also show the importance of the colloidal scale for the swimming speed of the bacteria [3].

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* Author for Correspondence: eric.grelet@crpp.cnrs.fr

Electromechanical effects in ferroelectric nematic liquid crystals

Marcell Máthé[1], Kelum Perera[2,3], Md Sakshavat H. Himel[2], Robert J. Twieg[4], James Gleeson[2],
Péter Salamon[1], Antal Jákli[1,2,3*]

[1]Institute for Solid State Physics and Optics, Wigner Research Centre for Physics,
Budapest, Hungary
[2]Department of Physics, Kent State University, Kent OH, USA
[2] Materials Science Graduate Program and Advanced Materials and Liquid Crystal Institute,
Kent State University, Kent OH, USA
[4]Department of Chemistry and Biochemistry, Kent State University, Kent, OH, USA

The ferroelectric, dielectric and electro-optical properties of the recently discovered ferroelectric nematic liquid crystals have been intensively studied in the last five years. [1] So far, however, we have barely scratched the surface of the tantalizing aspects of FNLC behavior, including their electro-mechanical effects, as well as possible applications, both expected and unforeseen. By symmetry, ferroelectric nematics allow piezoelectricity, that is linear coupling between electric and mechanical properties even though the mechanical response of a fluid is not elastic as for piezoelectric crystals. Here will describe several electric fields induced mechanical responses of ferroelectric nematic liquid crystal materials.

First, we will present experimental results and theoretical considerations of electromechanical effects of ferroelectric nematic liquid crystal droplets coexisting with the isotropic melt. [2] In the center of the droplets a defect is present that moves perpendicular to a weak in-plane electric field, and then extends and splits in two at higher fields. Additionally, the entire droplet drifts along the electric field with a speed that is independent of the size of the droplet and is proportional to the amplitude of the electric field. After the field is increased above 1mV/μm the entire droplet gets deformed and oscillates with the field.

Second, we will discuss mechanical behavior of ferroelectric nematic fluid jets in electric fields as a function the frequency and magnitude of the field and the length of the jet. It is found that in electric field, the jets are stable with aspect ratios much higher than π, i.e., much higher than for Newtonian fluids and show transversal mechanical vibrations under longitudinal fields.

Third, we will describe converse piezoelectric (electric field induced mechanical vibration) of ferroelectric nematic films. We will show that FNLCs show strong linear effect in the audio frequency range. Details of the results and their interpretation will be also discussed.

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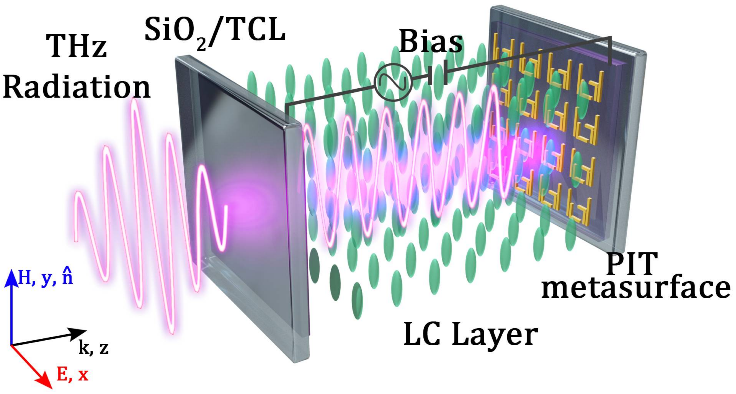
*Author for correspondence: ajakli@kent.edu

Electrically-Controlled Fano-Resonant Dual-Band Plasmon Induced Transparency Liquid Crystal Terahertz Meta-Switch

R. Kowerdziej [1], *I. Bisignano* [2,3], *M. Olifierczuk* [1], *R. Węglowski* [1],
A. Ferraro [4], *G. E. Lio* [5], *N. Pałka* [6], *R. Caputo* [7]

[1] *Institute of Applied Physics, Military University of Technology, 2 Kaliskiego St., 00-908, Warsaw, Poland*
[2] *International Center for Materials Architectonics (MANA), National Institute for Materials Science (NIMS), Tsukuba, Ibaraki 305-0044, Japan*
[3] *Faculty of Pure and Applied Sciences, University of Tsukuba, Tsukuba, Ibaraki 305-8577, Japan*
[4] *Consiglio Nazionale delle Ricerche – Instituto di Nanotecnologia (CNR-Nanotec), via P. Bucci cubo 33c, Rende, CS, 87036, Italy*
[5] *Physics Department, University of Florence, Via Sansone 6, Sesto Fiorentino, (FI), 50019, Italy*
[6] *Institute of Optoelectronics, Military University of Technology, 2 Kaliskiego St., 00-908, Warsaw, Poland*
[7] *Physics Department, University of Calabria, via P. Bucci cubo 31c, Rende, CS, 87036, Italy*

Active and hybrid Fano-resonant plasmon induced transparency (PIT) metasurfaces are identified as an emerging technology in terahertz optics. Here, we present electrically-controlled hybrid PIT metasurface platform by incorporating nematic liquid crystal into metallic meta-atoms for active shaping of terahertz group index. Importantly, the PIT metadevice exhibits a Fano-resonant response via near-field coupling of chiral and achiral meta-atoms and thus provides an effortless approach for both controlling nonlinear THz generation and suppressing radiative losses through lineshape engineering. Our findings provide evidence to support Fano-resonant active metasurfaces as compelling candidates for next-generation sensitive media for chemical or biosensing, and state-of-the-art nonlinear and slow-light devices [1].



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Shape and Dynamics of Nematic Droplets

Oleg D. Lavrentovich[123*]

[1]Advanced Materials and Liquid Crystal Institute, Kent State University, Kent, 44242 OH, USA
[2] Physics Department, Kent State University, Kent, 44242 OH, USA
[3] Materials Science Graduate Program, Kent State University, Kent, 44242 OH, USA

Balance of surface and bulk interactions define the properties of finite-size condensed matter, such as shape and electrophoretic propulsion in an external electric field. This presentation discusses how the shape and electrophoresis of nematic droplets are affected by bulk structural order and elasticity.

1. Usually, nematic droplets are of a spherical or tactoidal simply-connected shape. We observe experimentally a topological transformation from a sphere-like to toroid-like topology with the reduction of the Euler characteristic from 2 to 0 in droplets of lyotropic chromonic nematics. The nematic droplets form in the biphasic nematic-isotropic coexistence and transform when either the temperature or concentration increase. The effect is attributed to the elongation of the chromonic aggregates which results in the increase of the splay elastic constant K_{11} but does not affect the bend constant K_{33}. The toroidal shape accommodates only bend deformation of the director and avoids splay at the expense of the enlarged tension energy.

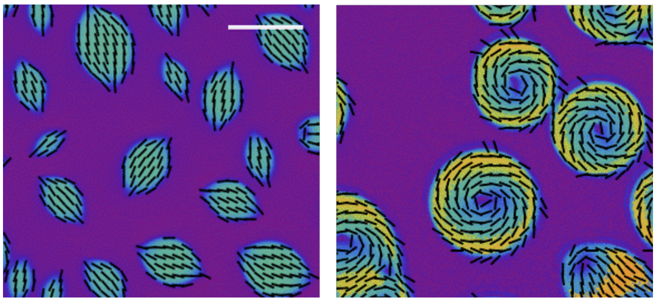

Figure 1. Topological transformation from spheroids (left) to toroids (right) of chromonic nematic droplets upon concentration increase. Note splay and bend deformations of the director field in spheroids and prevalence of bend in toroids. Scale bar 10 µm.

2. Electrophoresis is the dynamics of colloidal inclusions in a fluid, driven by a uniform electric field. We report on electrophoresis of ferroelectric nematic (N_F) droplets. When a direct current (dc) field is applied, N_F droplets propel along the field direction. An alternating current (ac) field results in a biased oscillatory motion of the droplet, which yields a net displacement over several cycles. The direction of the net displacement is set by the polarity of surface anchoring imposed through the bounding plates. The mechanism is attributed to the electric polarization reorientation in response to the field.

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* Author for Correspondence: olavrent@kent.edu

Distributed Feedback Lasing from Soft Matter: Exploring Polymer Dispersed Liquid Crystals, Chiral Liquid Crystal Microfluidic Droplets, and Photomobile Polymers

Daniele Eugenio Lucchetta[1]*, Gabriella Cipparrone[2], Andrea Di Donato[3], Riccardo Castagna[4]
and Oriano Francescangeli[1],

[1]Dip. SIMAU, Università Politecnica delle Marche, Ancona, Italy
[2]Dip. Di Fisica, Università della Calabria, Ponte P. Bucci 31B, Cosenza, Rende, 87036, Italy
[3]Dip. DII, Università Politecnica delle Marche, Via Brecce Bianche, 60131 Ancona, AN, Italy
[4]URT-CNR@UNICAM, Photonics and Sensors Materials Laboratory, Consiglio Nazionale delle Ricerche (CNR), Università di Camerino (UNICAM), Camerino, MC, Italy

Soft matter systems offer unique opportunities for achieving tunable and responsive lasing devices with enhanced functionalities. This contribution presents an overview of our research in the field of lasing from soft matter materials, focusing on three distinct areas: polymer dispersed liquid crystals (PDLCs), chiral liquid crystal microfluidic droplets, and photomobile polymers. Polymer dispersed liquid crystals (PDLCs) represent a versatile platform for lasing applications. PDLCs consist of liquid crystal droplets dispersed in a polymer matrix, offering a combination of the liquid crystal's inherent optical anisotropy and the structural stability provided by the polymer. By incorporating laser dyes into the polymer matrix, PDLCs can exhibit amplified spontaneous emission (ASE) or lasing behavior under appropriate excitation conditions [1-7]. The morphology and distribution of the liquid crystal droplets, as well as the polymer matrix properties, can be tailored to achieve control over the lasing characteristics, such as emission wavelength, threshold, and tunability. Chiral liquid crystal microfluidic droplets have emerged as a promising platform for achieving lasing with unique chiral characteristics. By encapsulating chiral liquid crystals within droplets generated in microfluidic systems in a thermally stabilized environment, lasing action can be achieved [8].

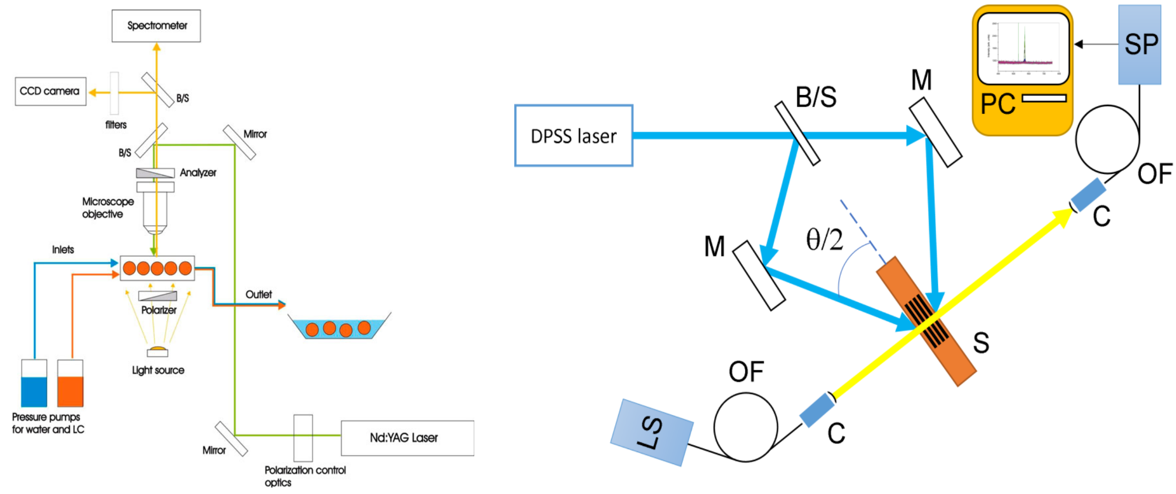

Figure 1. Experimental setups used to generate chiral LC microfluidics droplets (left) and to write DFB structures in photosensitive materials (right)

The photonic bandgaps (PBGs) can be theoretically calculated and experimentally measured as a function of temperature. A wide tuning effect of hundreds of nanometers were experimentally observed for the main PBG and reported for two different concentrations of the chiral dopant used to give chirality to the nematic LC. A single-droplet lasing effect is reported and optimized by using a stop flow technique and the dynamic of the reorientation inside the droplets observed under a polarized optical microscope integrated into the experimental setup. Finally, photomobile polymers offer a distinct approach to achieve lasing based on the dynamic control of the emission properties [9-11]. These polymers undergo reversible structural changes upon light irradiation, leading to a change in their refractive index and emission characteristics including laser directionality. The ability to externally control the lasing behavior through light stimuli provides opportunities for applications in reconfigurable photonic devices, optical memories, and optoelectronic systems. In summary, lasing from soft matter materials, including polymer dispersed liquid crystals, chiral liquid crystal microfluidic droplets, and photomobile polymers, offers exciting prospects for developing versatile and functional lasing devices. These systems harness the unique properties of soft matter, such as tunability, responsiveness, and self-assembly, to enable tailored lasing behavior for various applications in optics, photonics, and beyond.

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* Author for Correspondence: d.e.lucchetta@univpm.it

Ferroelectric sessile droplets on ferroelectric solids: electromechanical instability and other phenomena

L. Lucchetti

Dipartimento SIMAU, Università Politecnica delle Marche, via Brecce Bianche, 60131 Ancona, Italy

E-mail: l.lucchetti@univpm.it

The recent discovery of the ferroelectric nematic phase, N_F, opened a new chapter not only for the liquid crystal community, but in the whole condensed-matter physics. Beside adding a new, very peculiar, member to the group of ferroelectric materials, the new phase offers a broad range of physical effects to explore, ranging from the behavior of topological defects to surface anchoring, response to low frequency electric fields and light, interplay of bound and free electric charges, viscoelastic properties, field-controlled hydrodynamics, field-order coupling in both the N_F and the pre-transitional regions, behavior in confined geometry, just to cite a few examples. In this scenario, we recently performed experiments devoted to characterize the behavior of sessile N_F droplets on ferroelectric solid substrates and found that the combination of fluidity and polarity gives rise to an electromechanical instability induced by the coupling of the liquid crystal polarization with that of the solid substrate. This latter can be induced both pyroelectrically by temperature variation and photovoltaically through light irradiation. Such a polarizations coupling is a new phenomenon, observable thanks to the peculiar fluid nature of the ferroelectric nematic phase. With the aim of analyzing it, we performed additional experiments in different configurations and found other intriguing effects such as the optical control of the motion of small ferroelectric droplets over ferroelectric substrates, the actuation of ferroelectric fluid jets and the existence of a polarization coupling in conditions of no direct contact between the two ferroelectric materials. In this talk our results about the interaction between ferroelectric liquid crystal sessile droplets and ferroelectric solid substrates will be reviewed.

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From Ferroelectric Nematics to Smectics

Joseph Maclennan

Department of Physics, University of Colorado Boulder, Boulder, CO 80309, USA

Nematic liquid crystals have been a hot topic of materials research since the 1970s, when it was discovered that their curious mix of fluid-like and solid-like behaviors could be used to control light and make low-voltage, low-power, lightweight information displays. Ferroelectric liquid crystal phases, first observed in tilted chiral smectics and bent-core smectics, are particularly attractive for applications as they respond can be switched much faster than nematics and in a bipolar fashion. The recent discovery of ferroelectric nematics has led to a resurgence of interest in the science of polar liquid crystal phases and their possible applications. In this talk, I will review some of the research on this elusive phase of matter performed by the Boulder group, including experiments on the recently discovered polar smectics.

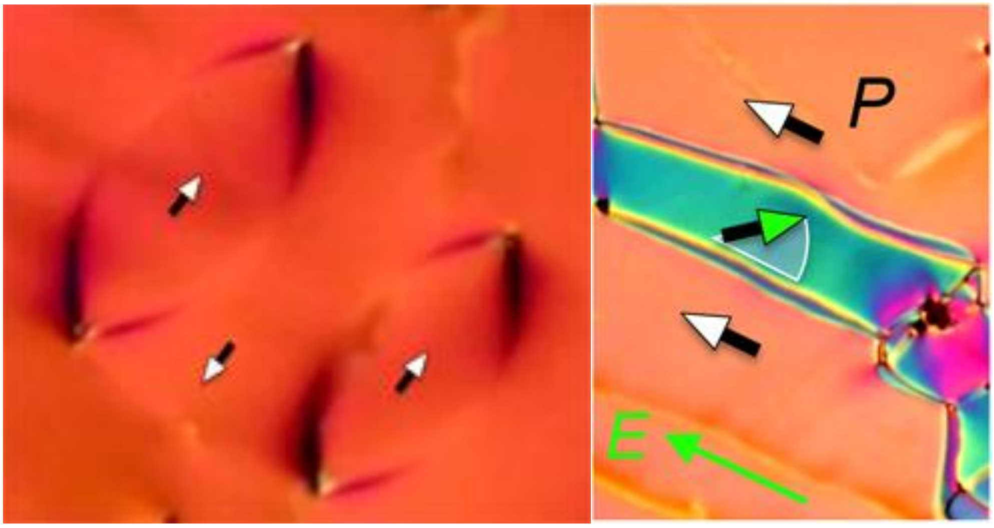

Figure 1. Polar domains and field response of RM734, a ferroelectric nematic liquid crystal.

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* Author for Correspondence: joseph.maclennan@colorado.edu

Photopatterning for the design of domains in ferroelectric nematic liquids

N. Sebastián[1*], M. Lovšin[1,2], B. Berteloot[3], N. Osterman[1,2], A. Petelin[1,2], R. J. Mandle[4,5], S. Aya[6,7], M. Huang[6,7], I. Drevenšek-Olenik[1,2], K. Neyts[2], A. Mertelj[1*]

[1]Jožef Stefan Institute, Ljubljana, Slovenia
[2] University of Ljubljana, Faculty of Mathematics and Physics, Ljubljana, Slovenia
[3]Liquid Crystals and Photonics Group, ELIS Department, Ghent University, Belgium
[4]School of Physics and Astronomy, University of Leeds, UK
[5]School of Chemistry, University of Leeds, UK
[6]AISMST, School of Emergent Soft Matter, South China University of Technology, Guangzhou, China
[7]Guangdong Provincial Key Laboratory of Functional and Intelligent Hybrid Materials and Devices, South China University of Technology, Guangzhou, China

Ferroelectric nematic liquids [1,2] are unique in combining 3D fluidity with ferroelectric properties[3]. Similarly, as in any ferroic materials, domains and domain walls are an integral part of their structures, and the ability to control them is crucial for studies of their fundamental properties and even more for applications. In this talk, I will focus on exploiting the coupling between polarization and splay deformation [4] for the design and realization of polarization structures[5]. Our study shows that splay deformation induced by photopatterned surface anchoring defines the orientation (including sign) of the polarization vector. We demonstrate the creation of periodic polarization structures and the possibility of guiding polarization by embedding splay structures in uniform backgrounds. An important aspect of this approach is understanding how the depolarization field and free ions affect the formation of the structures. The demonstrated capabilities of polarization patterning, open a promising new route for the design of ferroelectric nematic-based photonic structures and their exploitation.

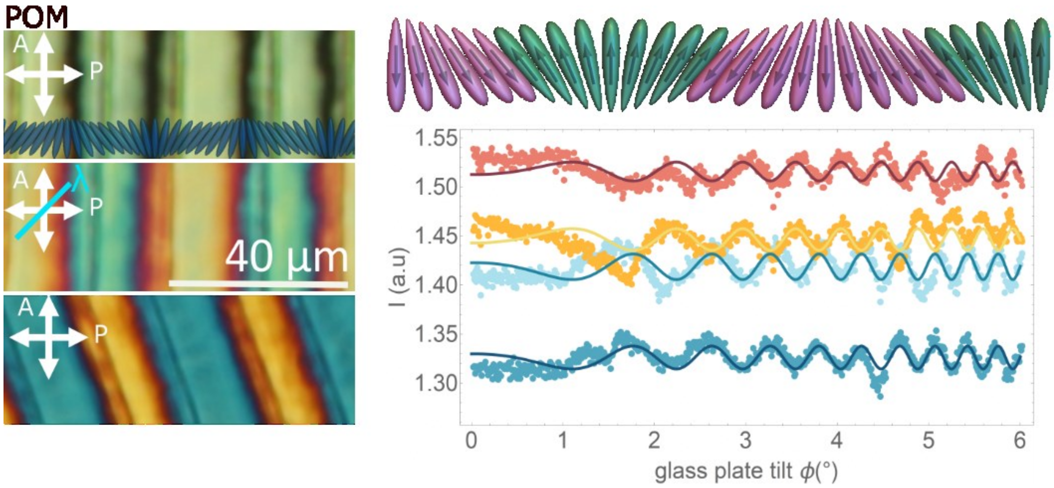

Figure 1. Example of a periodic splay photopatterned cell filled with DIO, showing the domains with alternating direction of polarization as demonstrated by SHG interferometry measurements.

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* Author for Correspondence: alenka.mertelj@ijs.si

Polymer stabilized liquid crystals for linear and nonlinear photonics

Sara Nocentini[1,2*], Federico Massarelli[1], Serena Salvestrini[1], Giuseppe Emanuele Lio[1,3], Diederik Sybolt Wiersma[1,2,3] and Francesco Riboli[1,4]

[1]European Laboratory for Non-Linear Spectroscopy (LENS), Sesto Fiorentino 50019, FI, Italy
[2]Istituto Nazionale di Ricerca Metrologica (INRiM), Turin 10135, TO, Italy
[3]Physics Dept., University of Florence, Sesto Fiorentino 50019, FI, Italy
[4]Nation Institute of Optics - National Research Council (CNR-INO), Sesto Fiorentino 50019, FI, Italy

The implementation of multi-functional integrated photonic and cryptographic platforms demands for nonlinear and reconfigurable materials that can efficiently modulate light propagation.
In this context, we report on the linear and nonlinear response of dye-doped polymer stabilized liquid crystal (LC) formulations that can micro-structured via phase separation processes or UV lithography resulting in complex disordered media and 2D micro designs respectively.

The remarkable tunable birefringence of liquid crystals and polymer stabilized LCs allow an efficient modulation of the local refractive index. In this way, by playing on an external stimulus that drives the phase transition, it is possible to spatially modulate the scattering potential of a LC based disorder medium, therefore profoundly modifying their equivalent transfer matrix. We report on the light control of the linear optical function that be reversibly or permanently modified depending on the LC formulations.[1]

On the other hand, LCs are well-known materials with large optical nonlinearity. Among the different nonlinear optical responses, the Kerr effect consists in the dependence of the material refractive index on the intensity of the light that propagates through the sample.
We present a systematic study on the nonlinear refractive indices of different nematic (polymer stabilized) LC mixtures mapping the nonlinear optical response to low-power continuous-wave lasers. By using the so-called Z-scan set-up [2-3], we mapped the Giant optical nonlinearity of dye-doped and polymer-stabilized LCs as a function of the dye concentration and the polymeric network, that both affect the nonlinear response even in not-resonant conditions.
The polymer stabilized LC formulation enabled the micro-pattering of nonlinear structures in which the not-resonant condition limits the propagation losses, a fundamental parameter in photonic applications.

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* Author for Correspondence: s.nocentini@inrim.it; nocentini@lens.unifi.it

Ferroelectric nematic phase formed by dimethylamino-terminated molecules

Vladimíra Novotná*, Martin Cigl, Natalia Podoliak, Lubor Lejček, and Tomáš Landovský

Institute of Physics of the Czech Academy of Sciences, Na Slovance 2, Prague, Czech Republic

Since the recent discoveries, ferroelectric nematics have become of upmost interest due to their outstanding ferroelectric properties [1,2]. After the experimental confirmation of ferroelectric nematic phase (N_F), the ongoing research is concentrated on the design of new molecular structures. Calculations and models for molecular structures were employed to predict ideal conditions for the N_F phase presence, including a dipole moment value, aspect ratio, the length of the molecule as well as the dipolar angle [3]. In spite of the fact that these conditions are rather restrictive, the development in the design of the promising molecular structures was promoted. Nevertheless, the library of N_F materials has been limited to a couple of structures up to now.

We have designed and prepared a new molecular structure, different from the previously reported systems [1,2] to support the N_F phase and optimize the physical properties. We report on a series of polar molecules revealing a ferroelectric nematic phase (N_F) directly on cooling process from the isotropic phase. An innovative structural motif of the mesogenic molecule (Figure 1) was optimized by the prolongation of the side-chain and the N_F phase was found for all homologues.

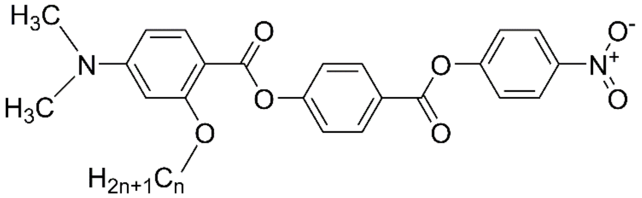

Figure 1. Chemical formula of the studied molecules, n number varied from 2 to 6.

The ferroelectric behaviour of the studied series of nematogens was investigated by dielectric spectroscopy, second harmonic generation, polarisation current measurements and by the analysis of the textures in polarised light. We studied the textures in different geometries, with the homogeneous (HG) treatment ensuring the molecular orientation being parallel to the glass surface and the homeotropic (HT) geometry with the molecules perpendicular to the sample surfaces. We concentrate on twisted domains, which are very frequent in the HG geometry with antiparallel rubbing. By fast cooling from the isotropic phase (with a rate >20 K/min), we reached the twisted domains extended over a large area (Figure 2). The borderline between the twisted domains is oriented approximately perpendicular to the rubbing direction. When we turn the analyser from the crossed position at an angle ~ 20 degrees clockwise or anticlockwise, we can distinguish two kinds of domains. The sense of twist is opposite for two neighbouring domains and they are separated by a 2π disclination line. The schematic picture of the molecular twist between the surfaces with antiparallel alignment is shown in Figure 2(b).

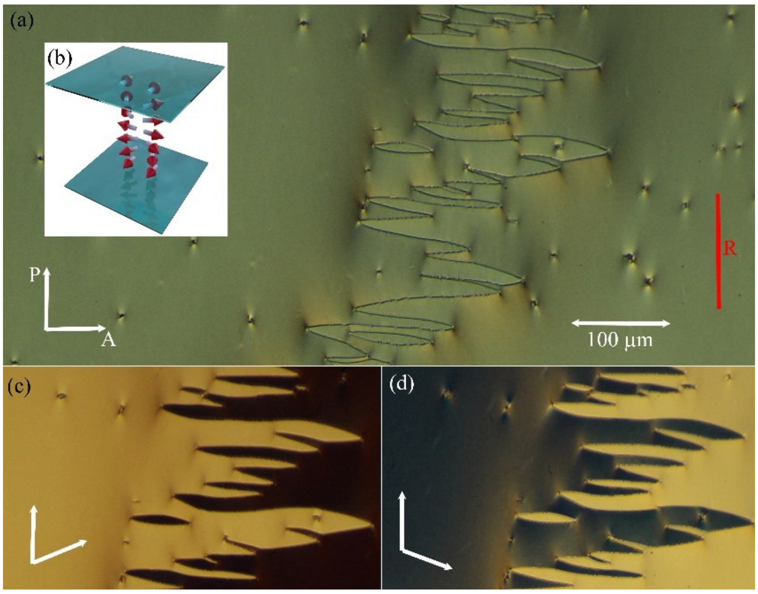

Figure 2. The textures observed in a polarising microscope for HG cell with antiparallel rubbing, (a) between crossed polarisers, the red arrow marks the rubbing direction, R, the orientations of the analyser (A) and the polariser (P) are schematically shown by white arrows. In figure (b) there is a schematic arrangement of the molecules in neighbouring twisted domains. The upper part of figure (a) is shown in (c) and (d) in an enlarged view with A rotated at an angle of about 20 degrees anticlockwise or clockwise from the crossed position.

The temperature dependence of polarisation is presented in Figure 3 for the homologue with n=5. We performed dielectric spectroscopy in a broad range of frequencies 1Hz-1MHz, from the isotropic liquid to room temperatures, to obtain the information about the molecular dynamics. In the ferroelectric N_F phase, we found one distinct relaxation mode appearing at the Iso-N_F phase transition on cooling and a very high dielectric constant (>10^4) was detected. Additionally, the ferroelectric character of the N_F phase was confirmed by SHG measurements.

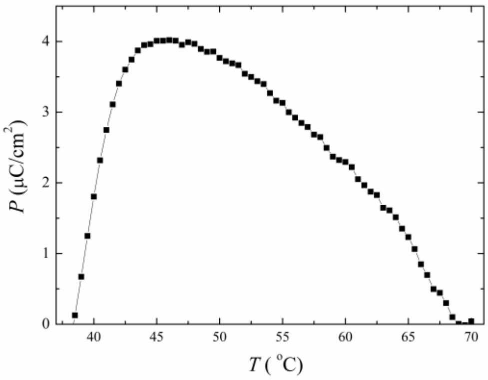

Figure 3. The temperature dependence of the polarization, P_s, for homologue with n=5. The polarization was calculated from a current profile detected at the triangular electric field of 10 Hz.

Currently, the studies of the microscopic organisation of the polar molecules and the mechanism of the phase transition to the ferroelectric nematic phase undergo an intensive progress. The polarity of the molecules with the strong susceptibility to the electric field represents a high potential for various applications.

Acknowledgment:
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* Author for Correspondence: novotna@fzu.cz

Peculiar Chiral Liquid Crystal Structures in Photonic Applications: from Photonic Crystals to Microlasers

Eva Oton[1*], Marcin Muszyński[2], Przemysław Morawiak[1], Rafał Mazur[1], Jacek Szczytko[2], Wiktor Piecek[1]

[1]Institute of Applied Physics, Military University of Technology, Poland
[2]Institute of Experimental Physics, Faculty of Physics, University of Warsaw, Poland

Chiral building blocks (i.e. molecules) of self-organized media leads to countless structural arrangements recognized in the macroscopic scale. It is observed in biological structures (cell-level chirality, a snail shell…) and liquid crystalline phases like cholesterics, blue phases, twist-bend nematics or chiral smectics. Chiral molecules with broken symmetry induce macroscopic chirality in the liquid crystal phases by forming their helical order. Such supramolecular structures, due to their reduced symmetry and topology, give rise to various intriguing properties to be exploited for optical and other purposes [1,2].

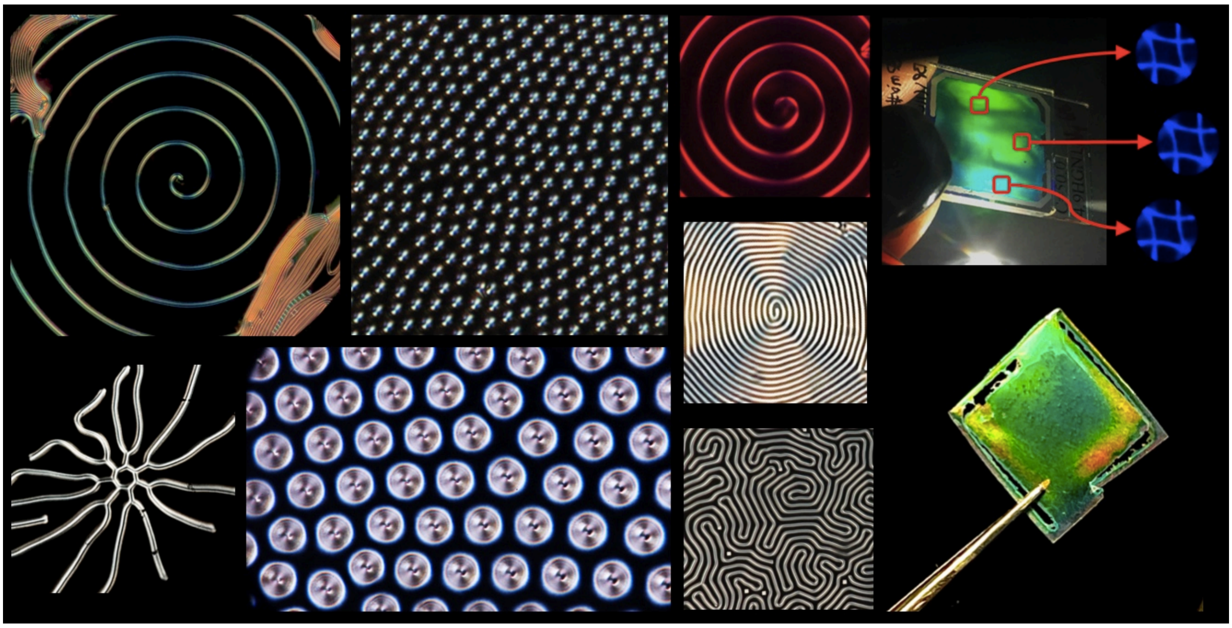

Figure 1. Different structures of chiral liquid crystal that were obtained with varying chirality and topological frustrations: from spheres and spirals to Blue Phases.

Doping of a nematogenic parent mixture with a chiral dopant induces a helical twist producing helical supramolecular structures with 1D, 2D or even 3D distribution of the helical axis in the free volume of such medium. By confining it between parallel glass substrates various structures, with different spatial orientation of the helical axis, can self-assemble. The most common, cholesteric liquid crystal (CLC) structure, exhibiting selective light reflection, is characterized by the uniform standing helix orientation.

In this presentation, we will focus on the more atypical chiral liquid crystal structures that we obtained for CLCs. A CLC helical axis spatial orientation can be distorted by imposing a topological frustration which tends to partly unwind the helical structure and induce, for instance, a fingerprint or a uniform lying helix (ULH) structure. Here the local helical axes are parallel to the glass substrates. Naturally, owing to its helical structure, a laying helix produces a 1D lattice with a variable periodic refractive index.

Further topological frustrations, achieved with diverse methods including confinement, smart surface treatment and external stimuli can induce more exotic structures characterized with sophisticated spatial distributions of the helical axis, forming, for instance, spirals or spheres, which introduce yet another level of unusual topological and non-linear properties [Fig.1].

Increasing chirality, blue phases (BP) appear, where the double twist helices self-organize in 3D cubic structures with nanometer range periodicity. They are regarded as 3D photonic crystals. BPs, however, tend to grow as small disorganized polycrystals, which produce scattering hence poor optical and electrooptical properties [3]. By imposing specific confinement and anchoring properties we have obtained BP photonic crystals of multi millimeter size with a uniform lattice orientation with excellent optical properties (Fig. 1 right). Moreover, with our method, it is possible to obtain large BP monocrystals with an arbitrary chosen spatial orientation of the lattice and predict the crystal orientation a given BP precursor mixture might produce [4].

In addition, our latest results show that when these chiral structures are doped with light-emissive compounds – like laser dyes – the system transits to a non-linear regime with emitted laser light that retains its characteristic polarization and angular features.

New approaches on technological procedures and using of smart functional dopants are imperative to make notable progress in fabrication of unique liquid crystal structures for photonic applications. The additional tunability in these structures by external fields opens up new possibilities in research of efficient light-emitting devices, including those with topologically protected spatial distribution of emitted light.

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* Author for Correspondence: eva.oton@wat.edu.pl

Excitation and tuning of optical Tamm states in a metal – polymer – liquid crystal stack

Victor Yu. Reshetnyak[1,2*], Igor P. Pinkevych[1], and Dean R. Evans[3]

[1]Physics Faculty, Taras Shevchenko National University of Kyiv, Kyiv 01601, Ukraine
[2]School of Physics and Astronomy, University of Leeds, Leeds LS2 9JT, United Kingdom
[3]Air Force Research Laboratory, Materials and Manufacturing Directorate, Wright-Patterson Air Force Base 45433, USA

Optical Tamm states (OTS) are localized electromagnetic modes formed at the interface between a metal film and a medium with the properties of a Bragg mirror. These states are optically manifested in the form of narrow resonance dips/peaks in the light reflection/absorption in the region of the Bragg mirror band gap. OTS can be excited at any angle of the light beam incidence without the need of a prism or grating, which makes them an attractive alternative to conventional surface plasmons in photoelectronic applications [1-3].

Liquid crystals (LC) can easily change their state under the action of external fields and therefore can be used in designs for controlling OTS [4,5]. For this purpose, holographic polymer-liquid crystal gratings (HPLCG), having a form of periodically alternating polymer-rich and nematic LC-rich layers, is proposed [6].

We theoretically study the excitation and control of the OTS in a hybrid structure with a metal film and a HPLCG taken as a Bragg mirror. HPLCG consists of 4-layer cells, where each cell is formed by a sequence of polymer-LC1-polymer-LC2 layers (Fig. 1). LC1 and LC2 differ only by the director direction, which can be controlled by a voltage applied to each LC layer. Such cells make it possible to control the OTS parameters in a wider spectral range than in the case of the 2-layer HPLCG [6].

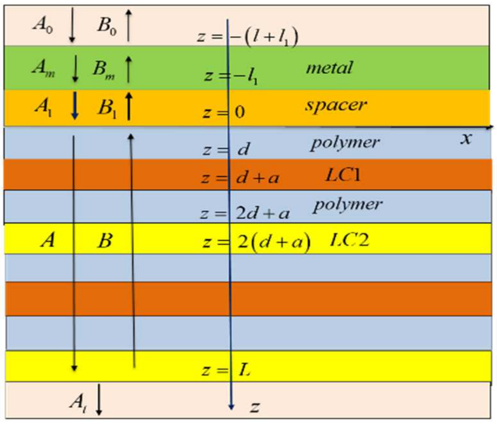


Figure 1. Schematic of the hybrid structure together with directions of the light beams in the system.

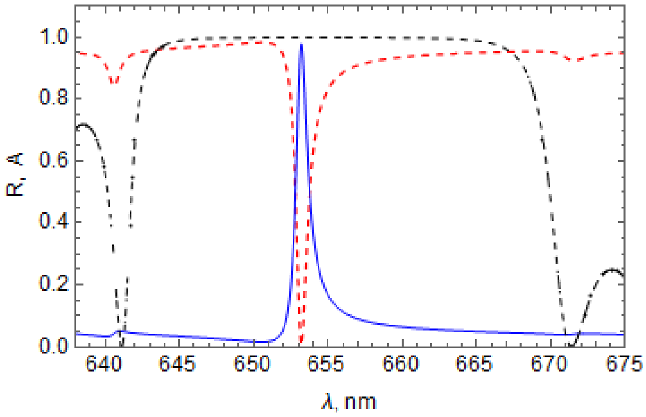
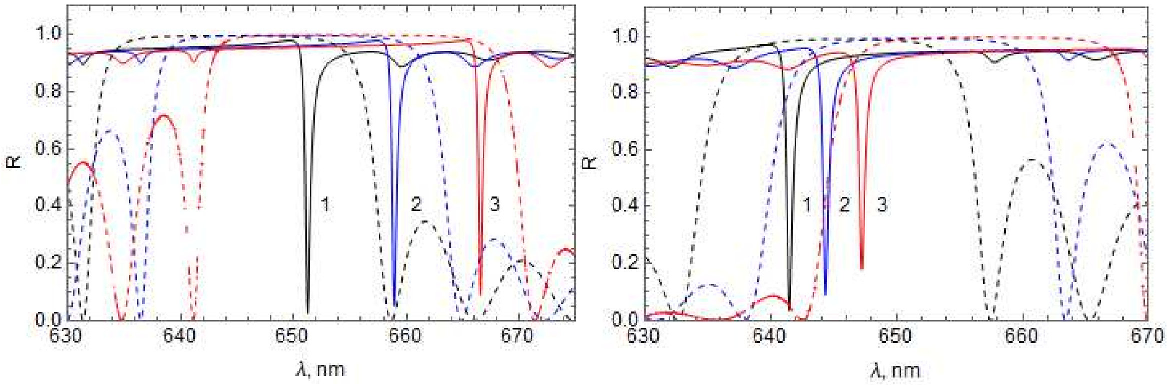


Figure 2. The reflection (dashed red) and absorption (blue) coefficients in the PLCG band gap region (dashed blue).

To study the spectral manifestation of OTS in the system shown in Fig. 1, it is necessary to consider the propagation of an incident light wave in the three constituent parts of the system, which are the metal film, the isotropic spacer, and HPLCG. By solving the wave equations for electromagnetic fields in the constituent parts of the system with appropriate boundary conditions, one can obtain analytical expressions for the magnitudes of forward and backward electromagnetic waves in each part of the system and calculate the reflection, transmission, and absorption coefficients of the system. We considered the normal incidence of a plane electromagnetic wave on a metal film, assuming that the wave is polarized along the *x*-axis, and the LC director is reoriented in the *xz*-plane. For calculations, it was assumed that the LC in all layers is 5CB, the metal film is Au, and the refractive index of the polymer is 1.7.

Figure 2 shows the obtained spectral distribution of the reflection and absorption coefficients of the system in the HPLCG band gap region for the case of a thick HPLCG when there is no transmitted light and the grating spacing is 200 nm. One can see that the dip in the reflection coefficient at a wavelength of 650.6 nm arises due to the light absorption by the OTS.



(a) (b)

Figure 3. Influence of the director angle ϕ of LC1 and LC2 on the OTS reflection dip. (a) $\phi(LC1) = \pi/2$, $\phi(LC2) = \pi/4 - 1, \pi/6 - 2, 0 - 3$; (b) $\phi(LC2) = \pi/2$, $\phi(LC1) = \pi/4 - 1, \pi/6 - 2, 0 - 3$.

Figure 3 shows the influence of the director angle with the *x*-axis, ϕ, in both LC layers of the HPLCG cell (see Fig. 1) on the reflection dip due to the OTS. It can be seen that at a fixed director angle in one LC layer of the cell, a change in the director angle in the other LC layer of the cell leads to a shift of the reflection dip, and this shift occurs in opposite directions if the director angle is fixed either in LC1 or in LC2 layers. The reflection dip depth also depends on the director angle values. At $\phi(LC1) = \phi(LC2)$ the HPLCG grating spacing becomes half as thick, which leads to a shift of the HPLCG band gap and the OTS to a wavelength region with half the values. The dependence of the OTS reflection dip on the thicknesses of the metal film, spacer, LC, and polymer layers, as well as on their refractive indices, was also studied.

The obtained dependences of the light reflection coefficient on the LC director orientation make it possible to control the spectral position and the depth of the reflection coefficient dip in the HPLCG band gap region using an external electric or magnetic field.

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* Author for Correspondence: victor.reshetnyak@gmail.com

From Chiral Nematics to Knotted Chiral Meta Matter

Ivan I. Smalyukh[1,2,3,4*]

[1]Department of Physics, University of Colorado, Boulder, CO 80309, USA

[2]International Institute for Sustainability with Knotted Chiral Meta Matter (SKCM^2), Hiroshima University, Hiroshima, Japan

[3]Materials Science and Engineering Program, University of Colorado, Boulder, CO 80309, USA

[4]Renewable and Sustainable Energy Institute, National Renewable Energy Laboratory and University of Colorado, Boulder, CO 80309, USA

Topological order and phases represent an exciting research frontier [1], but knots in fields were postulated to behave like particles already starting from Gauss and Kelvin. Experimentally they were found only as transient features and could not self-assemble into three-dimensional crystals. I will describe energetically stable solitonic knots that emerge in the physical fields of chiral liquid crystals and magnets [2,3]. While spatially localized and freely diffusing in all directions, they behave like colloidal particles and atoms, self-assembling into crystalline lattices with open and closed structures, as well as forming low-symmetry mesophases and gas- or liquid-like states [2,3]. A combination of energy-minimizing numerical modeling and nonlinear optical imaging uncovers the internal structure and topology of individual solitonic knots and the various hierarchical crystalline and other organizations that they form. These solitonic knots are robust [1-4] and topologically distinct from the host medium, though they can be morphed and reconfigured by weak stimuli like electric or magnetic fields. I will discuss their stability in molecular and colloidal liquid crystals of different symmetries [5-9] and will show how low-voltage electric fields can switch between the heliknoton [2,3] and hopfion [4] embodiments of such knot solitons while preserving their topology. Finally, I will discuss how this emergent paradigm of knotted solitonic matter could allow for imparting new designable material properties and for realizing phases of matter that so far could not be found in naturally occurring materials.

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* Author for Correspondence: ivan.smalyukh@colorado.edu

Oral Contributions

Photoinduced Birefringence Driven by Polarization Patterning in Liquid Crystalline Triblock Copolymers

Biagio Audia[1*], Miron A. Bugakov[2], Natalia I. Boiko[2], Pasquale Pagliusi[1,3], Gabriella Cipparrone[1], and Valery P. Shibaev[2]

[1]Physics Department, University of Calabria, Rende 87036, CS, Italy
[2] Faculty of Chemistry, Lomonosov Moscow State University, Moscow 119991, Russia
[3]CNR-Nanotec, c/o University of Calabria, Rende 87036, CS, Italy

Photochromic liquid crystalline block copolymers have attracted great attention in the last years as light-responsive materials due to their tunable features over multiple scales. This report is devoted to the study of photo-orientation processes in ABA type azobenzene-containing triblock copolymers composed by a nematic phenyl benzoate central block (B) and two polyvinyl pyridine side blocks (A) bound with azobenzene chromophores by hydrogen bonds (**Figure 1**). Different copolymers structurally distinguished by the length of the subblocks and by the ratio between the unities have been involved. A pump-probe technique based on the encoding of polarization holograms was used to evaluate the photo-response of the materials in terms of photoinduced linear birefringence [1]. Depending on the polymeric architectures, the supramolecular configuration self-organizes in different microphases that affect the material response. The possibility of optimising the induced anisotropy by thermal treatment and stabilizing the recorded structures by a simple chemical process has been demonstrated. Indeed, the azobenzene fragments can be easily removed by selective solvation, making the material transparent to the visible light. The acquired-photo stability of the recorded holograms makes these copolymers excellent candidates for the development of optical devices for light-shaping and polarimetric applications where illumination with white light or high intensity beams is needed.

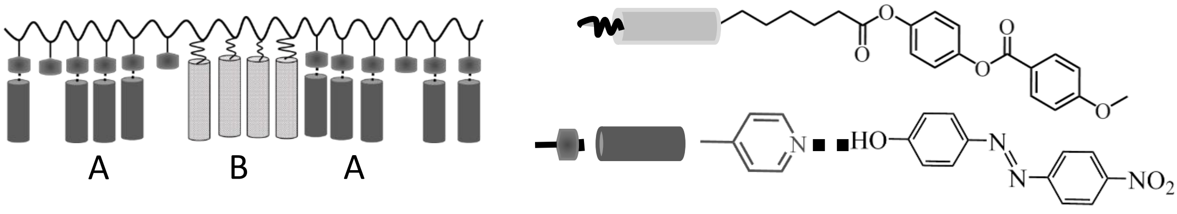

Figure 1: Chemical structure of the ABA type triblock copolymers

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* Author for Correspondence: biagio.audia@unical.it

Defect evolution in the smectic A-to-nematic phase transition in geometrically patterned confinement

Daniel A. Beller[1*], Jane Bernadette Denise M. Garcia[1], Mackenzie O'Keefe[2], Mohamed Amine Gharbi[2]

[1]Department of Physics and Astronomy, Johns Hopkins University, Baltimore, MD 21218, USA
[2] Department of Physics, University of Massachusetts Boston, Boston, MA 02125, USA

When subjected to hybrid anchoring conditions, thin films of smectic A (SmA) liquid crystals form focal conic domains (FCDs) to maintain constant spacing of their layers. Recent experiments have shown that the presence of 1D [1] or 2D undulations in one of the confining surfaces results in the formation of FCDs with nonzero eccentricity in the SmA phase, as well as the stabilization of disclination lines in the nematic phase. We model the evolution of defects in the SmA-to-nematic phase transition in this geometrically structured confinement by employing a multi-step Landau-de Gennes free energy relaxation procedure that accounts for FCD structure and self-organization in its initial conditions as well as changes in the nematic phase's bend Frank elastic constant close to the phase transition (Fig. 1). We find that the presence of 2D undulations along one surface results in the formation of metastable defect states in the nematic phase consistent with patterns observed in experiments, and that the winding structure of the nematic director at these disclination lines is dictated by the Gaussian curvature of nearby regions on the 2D undulated surface. By adding simulated nanoparticle (NP) inclusions to the modelled SmA configurations, we identify a sequential assembly mechanism in which NPs first decorate FCD defect lines but then coat the interfaces, accounting for an experimentally observed dramatic dependence of assembly morphologies on NP concentration.

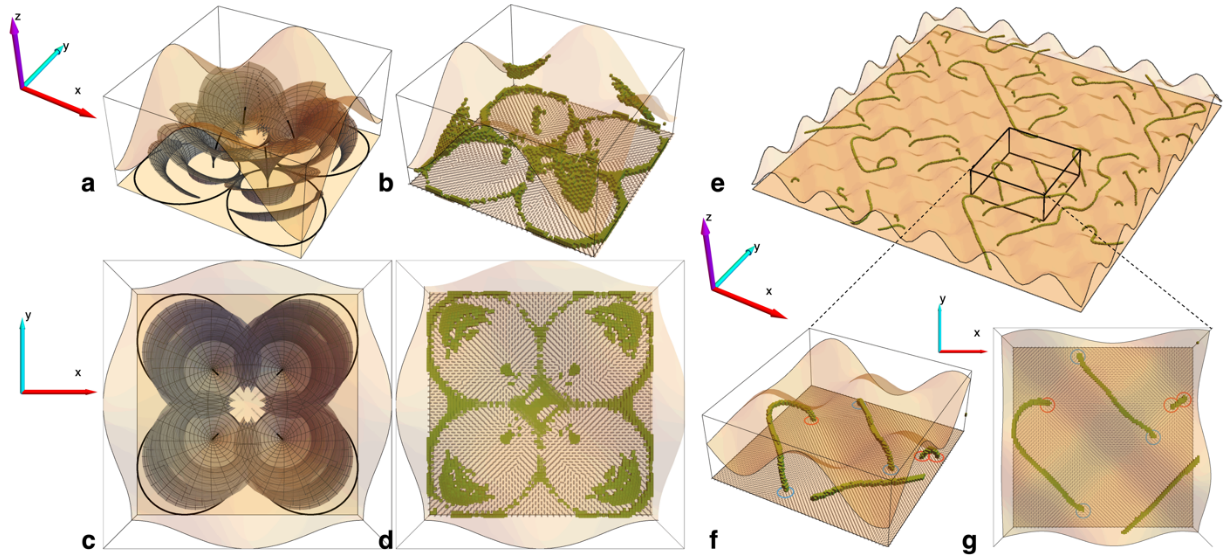

Figure 1. Numerical modeling of the defect evolution in the smectic A-to-nematic phase transition. (a and c) Schematic of the positions of the focal conic domains used to construct initial conditions for the Landau-de

Gennes free energy relaxation. (b and d) Topological defects (green) present after a relaxation at a ratio $K_3/K_1 = 8$ of bend to splay elastic constant. Gray rods represent the director field on the flat interface with degenerate planar anchoring. (e) A metastable array of disclination lines present after subsequent free energy minimization at $K_3/K_1 = 1$. (f and g) Two zoomed-in views of some of the defects in (e). Defect endpoints on the flat interface are encircled with blue (−1/2 winding) and red (+1/2 winding) circles.

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* Author for Correspondence: d.a.beller@jhu.edu

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Onsager theory of perfectly aligned rod like particles with longitudinal dipols - bifurcation analysis approach.

Agnieszka Chrzanowska[1*] and Lech Longa[2]

[1] Faculty of Materials Engineering and Physics, Kraków University of Technology, ul. Podchorążych 1, 30-084 Kraków, Poland
[2] Marian Smoluchowski Institute of Physics, Department of Statistical Physics and Mark Kac Center for Complex Systems Research, Jagiellonian University, ul. Łojasiewicza 11, 30-348 Kraków, Poland

Ferroelectric (polar) nematic phases are recently of great interest due to possible future applications and the number of liquid crystalline compounds that exhibit such ordering is on the increase. Most of these molecules have common features: strong longitudinal dipol moment and bulky lateral substituents. However, the microscopic origin of the polar properties of nematics still remains not fully understood. One of the theoretical approaches that allows to study the relation between the molecules shape anisotropy and the resultant phases is the Onsager density functional theory [1]. Within the framework of this theory enriched with the dipol moments interactions the possibility of polar nematic existence has been investigated for the model of hard spherocyllinders and for the model of rod like fused hard spheres of different shape aspect ratio under assumption of perfect alignment and different architecture of the assumed dipole moments. Basic element of the Onsager theory is the bifurcation analysis – a technique that allows to find the points at which a new symmetry solution bifurcates from an old branch - here perfectly aligned nematic. Since usually the bifurcation points are in the vicinity of the real transition points the bifurcation scenario is a good insight into the phase diagram. If the bifurcation analysis does not foresee a given phase – surely there will be no such a phase. In principle, the asumed particles here are of the cyllindrical symmetry, in the case of spheres it is however also possible to consider a wedge shape or consider a particle with a bulky lateral sphere. Due to a number of parameters used - the number of dipols, their orientations, positions and strengths and different shapes of particles a sort of machine learing must have been apllied. Also, since the density functional theory used is, as usual, of the second order type, the Parsons-Lee scaling [2,3] has been used to assess whether the packing fraction considered is within the nematic range.

ACKNOWLEDGMENTS
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* Author for Correspondence: agnieszka.chrzanowska@pk.edu.pl

The Influence of Terminal Chain Length on the Formation of the Ferroelectric Nematic Phase

Cruickshank, Ewan[1*]; Walker, Rebecca[1]; Ramsay, Shona[1]; Majewska, Magdalena M[2]; Pociecha, Damian[2]; Gorecka, Ewa[2]; Storey, John MD[1] and Imrie, Corrie T[1]
[1]Department of Chemistry, University of Aberdeen, Old Aberdeen, AB24 3UE, UK
[2]Faculty of Chemistry, University of Warsaw, ul. Zwirki i Wigury 101, 02-089, Warsaw, Poland

The conventional uniaxial nematic phase, N, although the least ordered liquid crystalline phase, is at the heart of one of the most successful optoelectronic technologies, namely liquid crystal displays. Within the nematic phase, the constituent molecules align along a common direction known as the director, **n**, whereas their centres of mass are randomly distributed. The director has inversion symmetry such that **n** = **-n**, and hence the phase is non-polar, **Figure 1 (a)**. The first reported experimental observations of a polar nematic phase were reported in 2017 for RM734, [1] and DIO [2]. In this polar phase known as the ferroelectric nematic phase, N_F, there is a spontaneous alignment of the molecular dipoles and the inversion symmetry present in the N phase is lost, i.e. **n** ≠ **-n**, and the phase is polar, **Figure 1 (b)**. The N_F phase has rapidly become the hottest topic in the field of liquid crystals not only because of the massive fundamental importance it has but also because the phase true application potential.

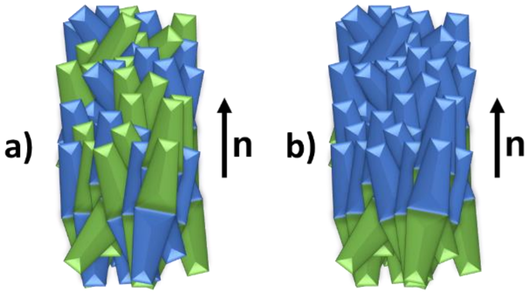

Figure 1. Schematic representations of the (a) conventional nematic phase, N, and (b) ferroelectric nematic phase, N_F.

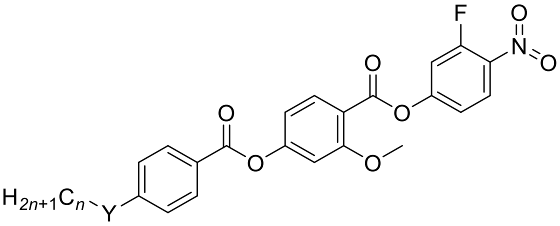

Figure 2. Molecular structure of the reported materials, where n = 0-5 and Y = O or CH_2.

There are around 200 compounds to date which have been shown to exhibit the N_F phase [3-5] and improving the structural design of these materials requires a better understanding of structure-property relationships associated with the N_F phase and these remain at an embryonic stage. Here we report the transitional properties of a series of materials with a methoxy lateral group in the middle phenyl ring in which the N_F is observed, **Figure 2**. Certain members of this series also exhibit an additional mesophase, here called N_X, the nature of which will be discussed.

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*Author for Correspondence: s02ec1@abdn.ac.uk

Stabilization of Dense Liquid Crystalline Phases by Electrostatic Interactions: a Molecular Dynamics Study

Laura Dal Compare[1*], Flavio Romano[1], Eric Grelet[2], and Achille Giacometti[1]

[1]Dipartimento di Scienze Molecolari e Nanosistemi, Università Ca' Foscari di Venezia, Venezia Mestre 30170, VE, Italy
[2] Université de Bordeaux, CNRS, Centre de Recherche Paul-Pascal, Pessac 33600, France

Recent experimental results on suspensions of very long and thin, highly charged colloidal rods (fd-virus particles), show that the phase behavior is strongly affected when the range of the electrostatic interactions is increased, especially in the high particle packing fractions [1,2]. Here, we study by numerical simulations a fluid of hard rods interacting via a repulsive DLVO potential, using Molecular Dynamics. In details, we use LAMMPS with a set of fused charged overlapping beads to form the rod. We study the full phase diagram as a function of the rod concentration, the Debye screening length and of the temperature at varying rod aspect ratio. On increasing the screening length with other physical parameters fixed, we find both the Isotropic and the Nematic phase to be progressively destabilized in favor of the Smectic and of the Columnar phases, in line with Onsager's theory as the effective rod aspect ratio decreases. Interestingly, we show that the phase sequence could be further modified in the dense regime, and specifically that electrostatic repulsions promote Smectic and Columnar ordering.

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* Author for Correspondence: laura.dalcompare@unive.it

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Advancements on Liquid Crystal-based Reflectarray Antennas in mm-Wave

P. de la Rosa[1,2*], R. Guirado[2], G. Pérez-Palomino[2], E. Carrasco[2], M. Caño-García[1], X. Quintana[1]

[1] CEMDATIC, ETSI Telecomunicación, Universidad Politécnica de Madrid, Spain
[2] Applied Electromagnetism Group (GEA), Information Processing and Telecommunications Center (IPTC), ETSI Telecomunicación, Universidad Politécnica de Madrid, Spain
* Author for Correspondence: p.delarosa@upm.es

Devices operating in mm-Wave based on liquid crystal (LC) technology, such as Reconfigurable Intelligent Surfaces (RIS), Reflectarray Antennas (RA) and Metasurfaces, rely on the tunability of the electromagnetic properties of LCs. LC technology is promising for these devices due to its good performance at high RF frequencies, low cost and availability resulting from the wide range of existing LC-based optical devices. Since LCs have been optimized for optical frequencies, since optimization of these materials for RF is still happening, the state of the art in the mm-Wave range can be further enhanced.

The working principle of LC-based devices operating in the mm-Wave range stems from the ability of varying the dielectric permittivity tensor by rotation of the LC molecules. This induces a phase shift on the incoming beam, allowing for procedures such as beam forming and beam steering in 1D or 2D.

In optical devices, the LC cavity thickness is usually larger than the light wavelength. In the mm-Wave range, this would entail thicknesses of several millimeters, out of the range where LCs can be driven by external fields. Instead, resonant structures with cavity thicknesses in the range of $\lambda/50$ (Figure 1) are employed.

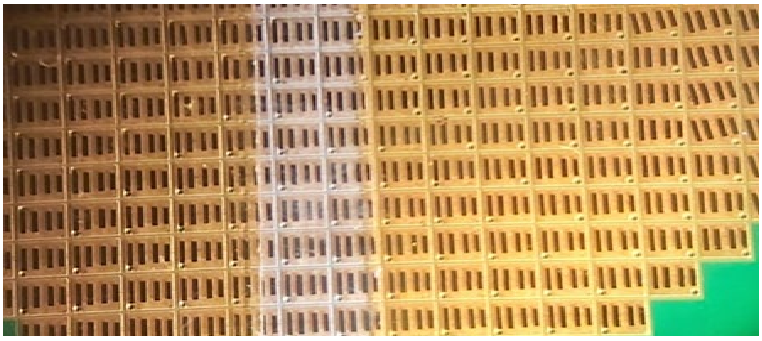

Figure 1. Resonant elements (dipoles) of an LC-based reflectarray antenna. The ground plane on the back is segmented to allow direct 2D addressing.

Implementation of these devices is still hampered by some drawbacks. LCs are driven by electric fields and elastic forces that decrease with cell thickness. Thick samples required by mm-Wave applications lead to slow reconfigurability times up to minutes to reach stationary state. Additionally, the loss tangent of LC materials in mm-Wave is yet to be optimized, and novel techniques may be needed to reduce it. Finally, direct addressing is employed in these devices both in 1D and 2D. Devices with higher number of pixels will require alternative procedures.

Several advancements regarding the temporal behavior of LCs in mm-Wave devices have been achieved. Three of them are presented here. The first technique, termed overdrive (OD), employs high voltage biasing signals to speed up the LC molecular rotation [1]. This technique only accelerates the field-induced rising times. The relaxation decay times, driven by the torque of the alignment layers, can be accelerated by embedding the LC into a polymer network (termed Polymer Network Liquid Crystal, PNLC) that induces an additional torque [2] reducing the relaxation time. The third technique makes use of Dual Frequency Liquid Crystals (DFLC), which are characterized by having a sign inversion of their dielectric anisotropy related to the frequency of the biasing signal [3]. This allows to accelerate both rising and decaying times, since both can be field induced at different biasing signal frequencies.

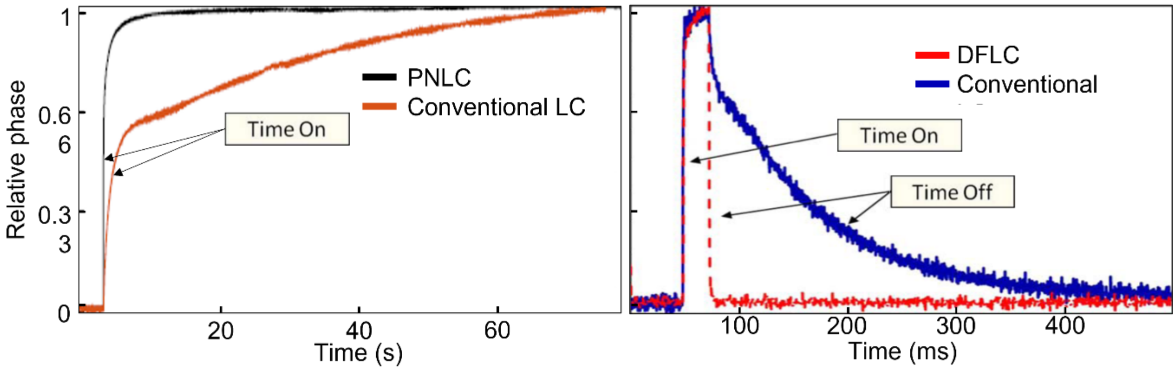

Figure 2. Reconfiguration time reduction for both PNLC (left) [2] and DFLC (right) compared to those of conventional LC at 100 GHz.

Direct addressing currently limits the device size. Adaptation of the active matrices used in optical devices to mm-Wave would allow to increase the number of independently driven pixels. This is of great interest since bigger devices, such as RIS, require large matrices of elements for proper functioning.

Other features have also been implemented, such as devices able to independently control the reconfiguration of each polarization. Additionally, optically transparent devices working in the mm-Wave range are being developed as well, with the aim of expanding the application areas of this technology (*e.g.*, placed in front of screens, solar panels, windows, etc).

In conclusion, LC-based reconfigurable devices for the mm-Wave range show great potential to enable the next generation of reconfigurable devices, required for upcoming networks at higher RF frequencies. However, some challenges are yet to be overcome.

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Multi-responsive microstructures based on Liquid Crystalline Networks

Simone Donato[1*], Daniele Martella[1], Sara Nocentini[1], Diederik S. Wiersma[1], Colm Delaney[2], Larisa Florea[2] and Camilla Parmeggiani[1]

[1]European Laboratory of non-linear Spectroscopy (LENS), Sesto Fiorentino 50019, FI, Italy;
[2] Department of Chemistry, Trinity College of Dublin, Dublin 2, Ireland.

The ability to fabricate materials able to perform actuation in a reliable and controlled manner is one of the primary needs for soft robotics [1]. In this field, Direct Laser Writing (DLW), a two-photon polymerization technique, is a very promising tool for the development of micrometric actuators providing novel solutions for reliably preparing of 3D micro-structures with a resolution up to of 100 nm [2]. In recent years, our research group has focused on the development of Liquid Crystalline Networks (LCNs) capable of performing reversible shape-changing under stimuli such as light irradiation or temperature variation. Different microrobots and photonic devices printed with light responsive LCNs by DLW has been reported [3,4].
In this communication, we will present the use of different polymerizable LC monomers to engineer the actuation properties under stimuli. Different molecular tweaks, such as LC mesogenic core or the ratio in between monomers, it is possible to affect the responsiveness of the materials. Furthermore, we demonstrate how varying the printing conditions, free-standing microstructures can be developed with suitable shape, as shown in Figure 1A and 1B.

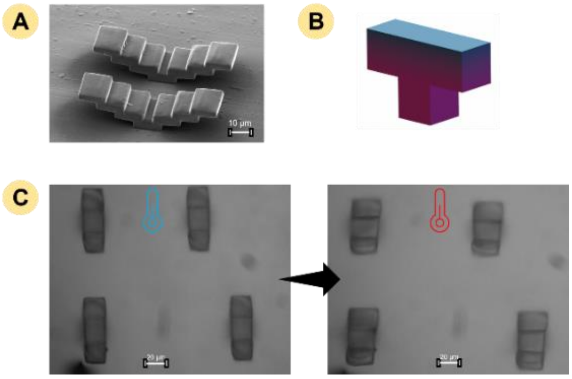

Figure 1. LCN microstructures printed by DLW. A) SEM of a 3-step stair; B) Project made for a free-standing table and C) Images of printed free-standing tables taken at low temperature (left) and high temperature (right).

An example of actuation of LCN microstructures is in Figure 1C. These multi-responsive microstructures are demonstrated useful not only in the field of micro-robotics, but also as a valuable tool in digital encryption keys.

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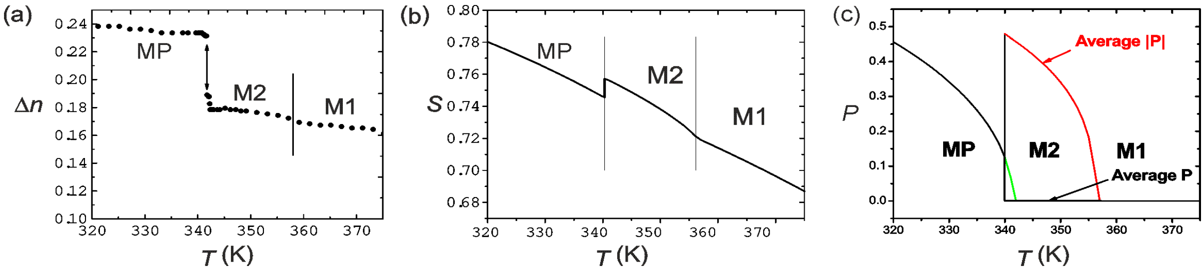
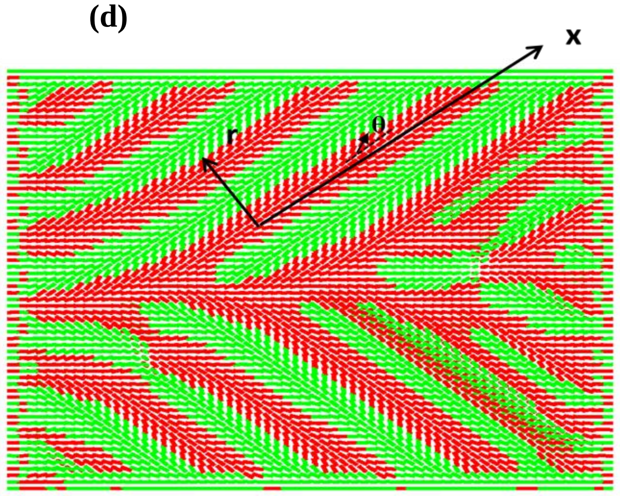
* Author for Correspondence: donato@lens.unifi.it

Ferroelectric and antiferroelectric splay nematic phases in a liquid crystal composed of polar molecules

Alexander Emelyanenko[1*], Vladimir Rudyak[1], Sergey Shvetsov[1], Fumito Araoka[2], Hiroya Nishikawa[2], and Ken Ishikawa[3]

[1]Lomonosov Moscow State University, Moscow, Russia
[2]RIKEN Center for Emergent Matter Science (CEMS), Saitama, Japan
[3]Tokyo Institute of Technology, Tokyo, Japan





We present experimental (a), theoretical (b-c) and computer simulations (d) findings about nematic phases arising in liquid crystals composed of polar molecules. The origin of proper and improper ferroelectricity is attributed to specific symmetries of molecular pair interaction [1]. M1 is paraelectric, MP is ferroelectric [2-3], and M2 is antiferroelectric [4] consisting of cylindrical domains. Non-polar *S* and polar *P* order parameters vary along *r;* *P* changes sign between the neighboring cylinders [red and green in (d)]. Local polarization in M2 is higher than in MP; average *P* is equal to zero in M2 and different from zero in MP. Transformation of all these phases in the presence of electric filed is also investigated.

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* Author for Correspondence: emel@polly.phys.msu.ru

Effect of the sample thickness on the measured dielectric spectra of a ferroelectric nematic liquid crystal

Aitor Erkoreka[1*], Josu Martinez-Perdiguero[1], Richard J. Mandle[2,3], Alenka Mertelj[4], and Nerea Sebastián[4]

[1] Department of Physics, Faculty of Science and Technology, University of the Basque Country UPV/EHU, Bilbao, Spain
[2] School of Physics and Astronomy, University of Leeds, Leeds, UK
[3] School of Chemistry, University of Leeds, Leeds, UK
[4] Jožef Stefan Institute, Ljubljana, Slovenia

The existence of a ferroelectric nematic phase (N_F), although predicted over a century ago, has only been recently confirmed in a handful of families of materials [1-3]. However, the fundamental question of how polar order emerges in these complex systems remains. One of the most useful tools to address this issue is broadband dielectric spectroscopy. The measurements reported using this technique thus far show extraordinarily large values of the dielectric permittivity, spanning at least two orders of magnitude around 10^3-10^5 (e.g. [3-7]). This raises the question of how measurement conditions influence the results and whether the reported values can be fully attributed to the material properties. Understanding the dielectric spectra of the N_F phase would help solving this fundamental issue, and could also help define and develop future applications.

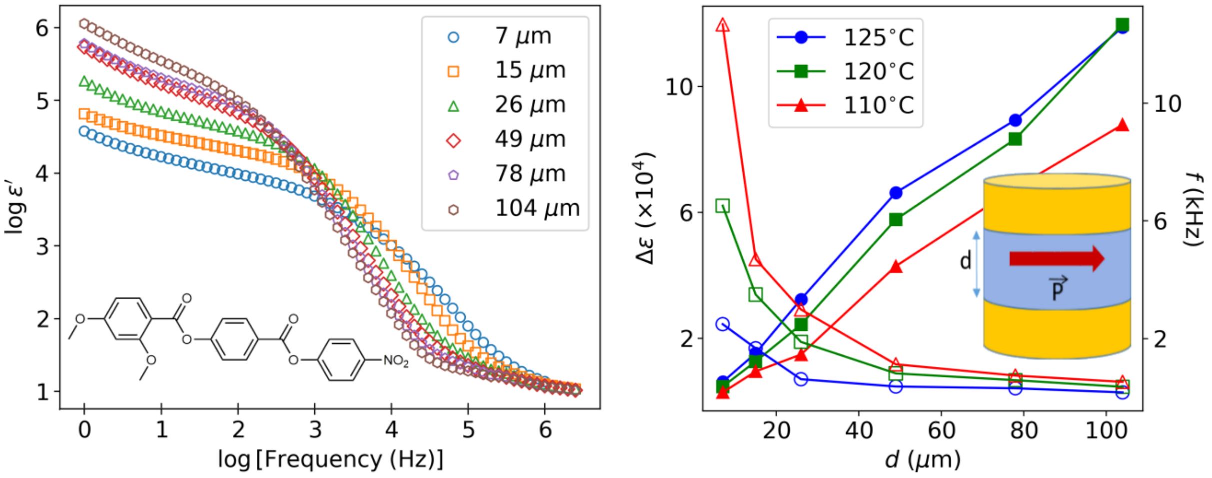

Figure 1. Left: Dielectric spectra of RM734 in the N_F phase for different cell thicknesses alongside its molecular structure. Right: Dielectric strengths and relaxation frequencies vs. cell thickness obtained from fits to the experimental data at three temperatures in the N_F phase. A schematic illustration of the measurement cell is also shown for reference.

In this contribution we present the results of a systematic investigation on the dielectric behavior of the ferroelectric nematogen RM734 by varying the thickness of the parallel capacitor measuring cell. While in the non-polar high temperature nematic phase results show only slight differences due to slight variations of the alignment, the dielectric strength of the characteristic relaxation process in the N_F phase shows a linear dependence on the cell thickness. Additionally, the relaxation frequency of this mode is found to be inversely proportional to the cell thickness. Finally, the obtained results are analyzed in terms of three different models: a polarization-external capacitance Goldstone reorientation mode [8], a recently developed continuous phenomenological model [9], and an electrode polarization model [10].

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* Author for Correspondence: aitor.erkorekap@ehu.eus

Dynamics of 2D-ribbons in liquid crystal topological defects

*L. Essaoui[1],J. Niyonzima[1], C.Tosarelli[1], C.Abadie[1],H.Jeridi[12], A.Vlad[3], A.Coati[3], S.Royer[1], D.Constantin[4], I.Vickridge[1], M. Goldmann[13], Y. Garreau[35], D.Babonneau[6], B.Croset[1], E. Lhuilier[1], E. Lacaze[1]

[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 Cite´, 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*

Smectic liquid crystals host a variety of topological defects [1, 2] where nanoparticles can be confined and organized [2, 3, 4] We have showed that the confinement induced by smectic patterns made of an assembly of oriented ribbon-like grain boundaries (2-dimensional topological defects) leads to the formation of oriented ribbons of fluorescent nanorods [5].
We are interested by the dynamics of these assemblies of nanoparticles in relation with the confinement within smectic topological defects. In solution the dynamics of nanoparticles is of Brownian-type. When it comes to more complicated systems such as liquid crystal nematic matrices, unusual dynamics can be already observed [6]. For assemblies of nanorods confined in grain boundaries the dynamics becomes very specific.

By coupling optical microscopy, fluorescence microscopy and synchrotron-based grazing incidence X-ray scattering (GISAXS), we relate the observed dynamics of the nanorods to the intrinsic structure of the smectic matrix. Firstly, we observe a unidirectional dynamics for the ribbons along the defects. It is characterized by two types of movements : small scale fluctuations (20-30nm) and jumps between two equilibrium positions separated by 130nm. Secondly, this jump value corresponds to the wavelength of an Helfrich Hurault instability recently evidenced within the defect [7]. Finally, this shows that this instability plays the role of a periodic energy barrier that induce a further confinement of the ribbons at equilibrium positions defined by the maxima of the Helfrich Hurault instability.

We demonstrate that to avoid this Helfrich Hurault instability driven confinement, the temperature has to be increased close to the smectic/nematic phase transition in order to make the instability vanish. A continuous motion of the nanorod ribbons is thus induced, allowing to connect neighbouring ribbons and finally elongate the ribbons up to lengths reaching easily 10 micrometers. This may allow in the future to connect two electrodes by single ribbons for future studies of transport properties within nanoparticle ribbons.

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* Author for Correspondence: essaoui@insp.jussieu.fr

The elasticity of lyotropic liquid crystal polymers and colloids

Davide Revignas[1*], Cristiano De Michele[2], and Alberta Ferrarini[1]

[1]Department of Chemical Sciences, University of Padova, Padova 35131, Italy
[2] Department of Physics, University of Roma "La Sapienza", Roma 00186, Italy

Lyotropic liquid crystals (LCs) include a variety of systems, which range from solutions of natural and synthetic polymers, such as DNA, collagen and cellulose, and linear aggregates of flat molecules (the so-called chromonics), to colloidal suspensions of elongated particles, such as nanocellulose, filamentous viruses and actin filaments. In determining the liquid crystal behavior of these systems, beside the contour length L and the diameter D, an additional scale comes into play, that is the persistence length l_p, which characterizes the particle stiffness. It affects the phase behavior and the response to mechanical deformations, which is of special interest for applications. The Frank elastic constants of lyotropic LC polymers are more difficult to measure than those of low molar mass systems and exhibit a wider diversity [1]. Two regimes are generally distinguished [2,3]: stiff chains, with to $L \gg l_p$, which are simply assimilated to rigid rods, and very flexible particles, with $L \ll l_p$, in which case each chain is thought of as a sequence of rigid rods, whose size depends on the persistence length and on the degree of orientational order. However, both experiments [4,5] and computer simulations [6,7] have demonstrated that these two limits do not correspond to the behavior of most systems, hence the need for a broader theoretical understanding has been pointed out.

Here, we present a microscopic theory for the elasticity of lyotropic LC polymers and colloids which, extending to chains endowed with flexibility an approach developed for particles with arbitrary shape [8], fully incorporates the coupling between orientational and conformational degrees of freedom and the director field. Numerical results for semiflexible chains show that flexibility has non-trivial and distinct effects on the elastic constants, which appear even for relatively stiff chains ($L < l_p$) and can be traced back to the interplay of particle shape and new types of order arising in the presence of deformations [9]. Such findings enable us to discuss experimental data reported in the literature for lyotropic LC polymers.

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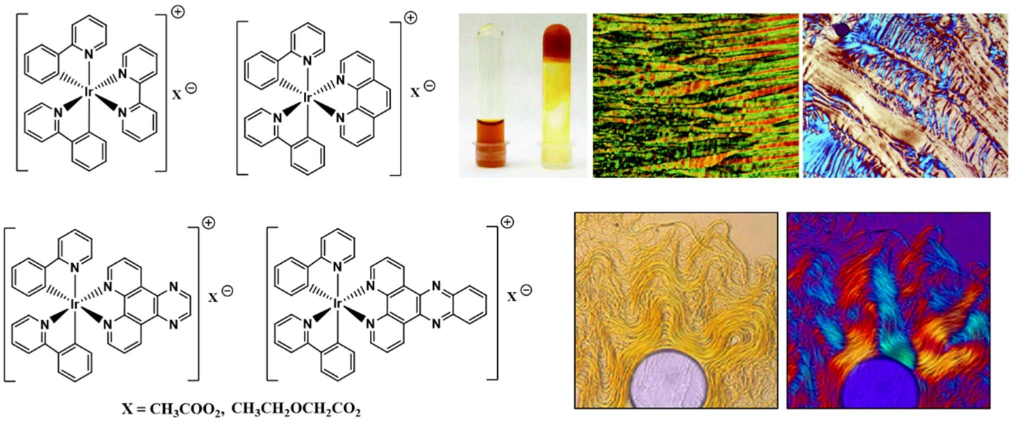
* Author for Correspondence: davide.revignas@studenti.unipd.it

Iridium (III) water-soluble cationic complexes between gels and lyotropic liquid crystals: A new class of chromonic liquid crystals ?

Nicolas Godbert[1*], Elisabeta I. Szerb[2], Francesca Scarpelli[1], Iolinda Aiello[1], Alessandra Crispini[1], Massimo La Deda[1], Loredana Ricciardi[3] and Mauro Ghedini[1]

[1]MAT-InLAB laboratory, Department of Chemistry and Chemical Technologies, University of Calabria, Rende 87036, CS, Italy
[2]"Coriolan Drăgulescu" Institute of Chemistry, Romanian Academy, 24 Mihai Viteazu Bvd., Timişoara 300223, Romania
[3]CNR NANOTEC-Istituto di Nanotecnologia, U.O.S. Cosenza, Arcavacata di Rende, CS; Italy

Chromonic liquid crystals have been defined by all water soluble lyotropic liquid-crystals that present a rigid aromatic flat core embedded with hydrophilic groups. The aqueous lyomesophases presented by chromonics are the consequence of face-to-face aggregation via π-π interactions of the aromatic cores that ordered molecules into columns. [1] Such definition, although well diffused, might be reconsidered. Lyotropic metallogens, whose molecular conformation might dramatically steps away from the flat geometry owe to the coordination mode of the metal ion, would hardly therefore be considered as chromonics liquid crystals. Indeed the first studied and identified examples were naturally square planar metal ions. However, since the last decade unconventional (for their shape) chromonics liquid crystals start to appear throughout the literature. Herein, we will described the synthesis and properties of a series of water-soluble octahedral Ir(III) cationic complexes that through the opportune choice of the counteranion can self-assemble in water solutions to form gel phases characterized by a high columnar supramolecular order, hence presenting all the features to be part of the chromonics sub-category of lyotropic liquid crystals.[2-5]



$X = CH_3COO_2$, $CH_3CH_2OCH_2CO_2$

Figure 1. Water soluble Ir(III) complexes presenting highly organized lyophases.

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* Author for Correspondence: nicolas.godbert@unical.it

On the Origin of High Charge Mobility in Discotic Nematic Mesophases Formed by Porphyrin-Core Dendrimers: an NMR Study

Attilio Golemme[1*], Alberto Concellòn[2], Josè Luis Serrano[3], Roberto Termine[1]
and Isabella Nicotera[4]

[1]CNR-Nanotec, Physics Department, University of Calabria, Rende 87036, CS, Italy
[2]Instituto de Nanociencia y Materiales de Aragón (INMA), CSIC-University of Zaragoza
C/Pedro Cerbuna 12, 50009 Zaragoza, Spain
[3]Department of Organic Chemistry, Faculty of Sciences-INMA University of Zaragoza
50009-Zaragoza Spain
[4] Departement of Chemistry and Chemical Technologies, University of Calabria, Rende 87036, CS, Italy

In the field of photonic and optoelectronic device development, researchers are currently producing efforts to replace inorganic materials with organic ones, as the latter introduce several advantages. However, the typical low charge mobility, that is a key parameter for different devices, is among the disadvantages. Self-organized materials are promising candidates to overcome this drawback. In particular, to increase charge mobility, the properties of columnar liquid crystals, where molecules spontaneously stack into columns to give one-dimensional structures of interacting systems, were often exploited. This organization induces a π-orbital overlap that allows a very efficient one-directional intracolumnar charge transfer, with the result of obtaining materials with high mobilities, comparable to that of amorphous silicon. More recently, discotic nematic mesophases formed by porphyrin-core dendrimers with high charge mobilities [1] have also been reported. Being nematic, such phases provide the important advantage of being easily orientable, with uniform director orientation over large distances and a very low defect density. As in the nematic phase the molecular organization does nor exhibit the long range positional order associated with stacks and π-orbital overlap, the origin of the recorded high mobility is an open question.

In order to gain insight into the matter, the properties of several different porphyrin-core dendrimers were investigated by using deuterium and proton NMR techniques. Temperature dependent deuterium powder patterns of a small deuterated probe and proton spin-lattice relaxation times confirmed the phase sequence already observed with other techniques. However, the most interesting results were obtained via pulsed-field gradient proton NMR diffusion measurements. Such data show that molecular aggregates (probably associated with short-range columnar order) form upon decreasing the temperature from the I to the N phase, but only with metal-containing porphyrins. This is in agreement with the observation that, although both metal-containing and metal-free porphyrins form nematic discotic mesophases, only in the nematic phases formed by metal-containig porphyrins charge mobility is high. Two conclusions can then be drawn: a) the metal of the porphyrin in necessary in order to induce intermolecular interactions leading to short-range columnar order and b) even relatively short range columnar order may be sufficient to induce high charge mobility.

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* Author for Correspondence: attilio.golemme@unical.it

Interplay of active nematic defects and flow structures

Louise C. Head[1], Claire Doré[2], Ryan Keogh[1], Kristian Thijssen[1,3], Teresa López-León[2] and Tyler N. Shendruk[*1]

[1]School of Physics and Astronomy, University of Edinburgh, Edinburgh, EH9 3FD, United Kingdom
[2] Laboratoire Gulliver, UMR CNRS 7083, ESPCI Paris, PSL Research University, 75005 Paris, France
[3]Niels Bohr Institute, University of Copenhagen, Blegdamsvej 17, Copenhagen 2100, Denmark

Active nematics are a class of liquid crystals driven out-of-equilibrium by the intrinsic activity of the rod-like constituents. In bulk, global nematic order is destabilised via the coupled feedback between nematic deformations and active flows, facilitating a steady-state population of pairs of half-integer nematic topological defects and chaotic flows (active turbulence). When confined, active nematics can exhibit active turbulence if the activity is sufficient, or more ordered spatiotemporal flow field patterns with a reduced defect count, dependent on the confinement scale. Understanding these complex flow regimes have naturally favoured perspectives centred on the nematic defects, as their emergent steady-state presence is an evident feature of active nematics. Defect orientation, motility and flow generation has been employed to study quasi-particle like descriptions of larger scale flow structures [1]. Within this description, the production of active flows around defects has been studied [2], revealing that the flow-field solution around a +1/2 defect is associated with two vortices and a self-propulsion velocity, while the -1/2 defect is associated with six vortices and active flows tending to zero at their core. However, this viewpoint is necessarily an oversimplification since flows are not simply governed by defects – flows influence the defects in parallel. The reverse viewpoint, 'how nematic defects respond to the structure of the flow field', is therefore important for understanding the architecture of active flow patterns but has not received adequate attention. Through experiments of microtubule-kinesin based active nematics [3], and mesoscopic simulations [4], we explore how defects couple to the structure of the velocity field in 2D. We adopt a topological description of the velocity field, identifying the borders between rotationally dominated and strain-rate dominated regions, which can be observed as the closed contours in Figure 1. We establish the importance of these boundaries as paths for defect dynamics and categorize defect behaviors into two regimes associated with +1/2 defects tracing either one boundary or instantaneously traversing intersections. These results demonstrate that the ideal picture of two vortices associated with each of the +1/2 defects is not characteristic of active nematics. Through utilizing topological descriptions of structures in the director field and velocity field, we can provide a complementary perspective on active nematic flows and possible control mechanisms by manipulating either field.

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* Author for Correspondence: t.shendruk@ed.ac.uk

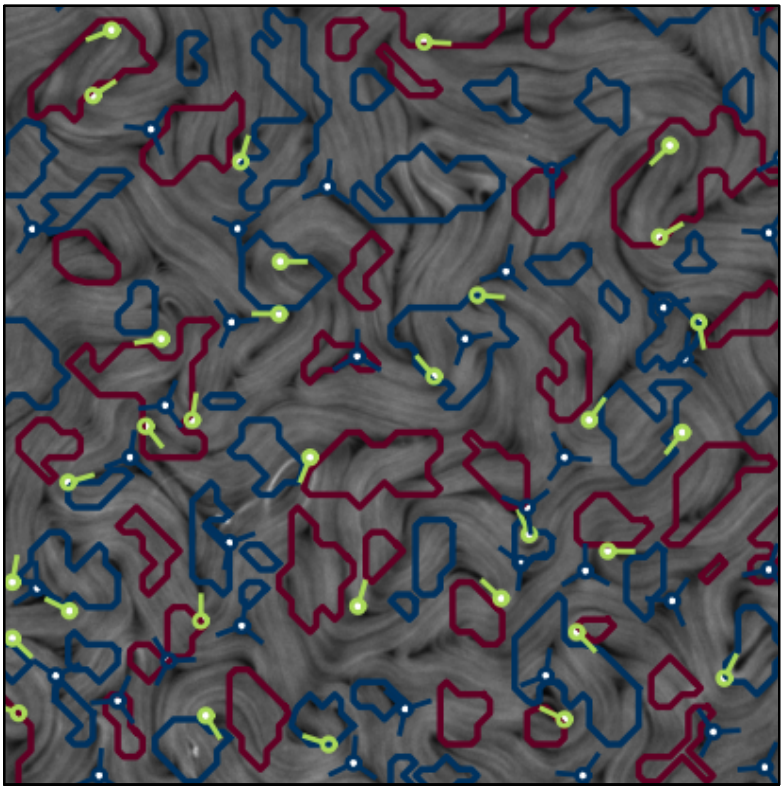

Figure 1. Experimental snapshot of +1/2 (green comet) and -1/2 (blue trefoil) nematic defects following the borders between vorticity and strain-rate dominated regions of the velocity field. Red borders enclose a clockwise vortex and blue for an anticlockwise vortex.

Using many-body dissipative particle dynamics to predict the properties of surfactant systems

Rachel Hendrikse[1*] and Mark R.Wilson[1]

[1]Department of Chemistry, Durham University, Durham, UK

Dissipative particle dynamics (DPD) is a coarse-grained simulation method, which can be used to study soft matter systems which require long simulation times and length scales, i.e. well beyond those accessible to molecular dynamics. However, a disadvantage of DPD is that the bead density of a system is roughly constant across a domain, leading to an inability to simulate vapor-liquid interfaces. This led to the development of many-body dissipative particle dynamics (MDPD), which allows density to vary across a system, allowing surface tensions to be calculated and improving the description of interfaces in soft matter systems. However, because of coarse graining, the parameters used in calculating force are not directly related to the molecular scale; therefore, one requires a parameterization to map beads to real systems. For MDPD, this is relatively under-researched and there are few parameterization schemes available for general systems.

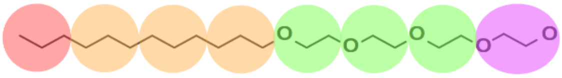

Figure 2. Surfactant molecules (e.g. C12E4) are coarse-grained into 'beads'.

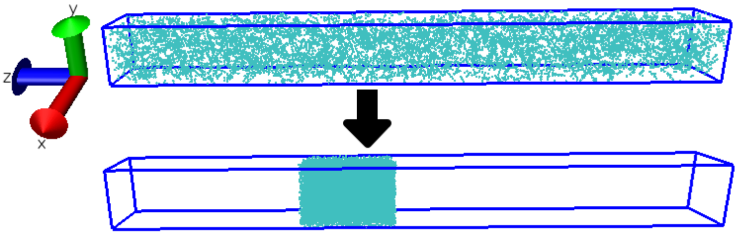

Figure 1. Formation of coexisting liquid and vapour phases from an initially random configuration.

In this work, we present a new parameterization scheme [1] for MDPD simulations based on experimental surface tensions, densities and chemical potentials. The parameterization is tested via application to various mixtures and surfactant solutions, and by comparison with experimental studies. We perform an in-depth study of nonionic polyoxyethylene alkyl ether surfactants, as well as zwitterionic surfactant lauryldimethylamine oxide, at the air/water interface. In particular, the influence of the number of ethylene oxide units in polyoxyethylene alkyl ether surfactants is investigated.

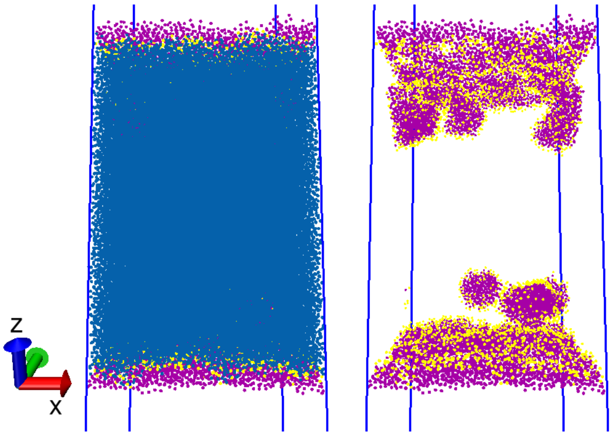

Figure 3. Overpacked surfactants at an air/water interface will be removed into the bulk to form micelles.

We show that our scheme correctly predicts surface tension as a function of surface coverage, together with surface phase transitions. Aspects of behaviour which are difficult to study experimentally, such as conformation and packing, are studied in detail, providing insight into the nature of water-surfactant interfaces. Moreover, we observe an orientational transition, from surfactants lying directly on the water surface at low surface coverage, to surfactants lying parallel or tilted with respect to the surface normal at high surface coverage. Additionally, key properties of micellar systems (such as CMC, aggregation number, micelle shape etc.) can be readily determined.

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Micellar lyotropic liquid crystalline physical gels – a new kind of anisotropic hydrogels

Michael Herbst[1], Sonja Dieterich[1], Thomas Sottmann[1], Cosima Stubenrauch[1]
and Frank Giesselmann[1*]

[1]Institute of Physical Chemistry, University of Stuttgart, 70569 Stuttgart, Germany

Micellar lyotropic liquid crystalline gels are a new class of soft materials in which the anisotropy of a lyotropic liquid crystal (LLC) is combined with the mechanical stability of a gel [1,2]. In a systematic research effort since 2017, we have succeeded to obtain hexagonal, lamellar and nematic LLC gels by adding appropriate low molecular weight gelators (LMWGs) to the respective LLC phase [3,4]. These anisotropic hydrogels show optical birefringence (Fig. 1a) and elastic response to mechanical deformation (Fig. 1b).

In this presentation we will give an overview of the fabrication, the structures and the properties of LLC gels. In addition, we will discuss their potential applications, such as their stimuli-responsiveness to variations not only in temperature, but also in concentration, pH value or vapor pressure. Possible applications of (nematic) LLC gels, e.g., as stimuli-responsive actuators, require a macroscopic alignment of both the nematic director and the fiber network. Macroscopic alignment, however, is a challenge if the sol-gel temperature of the gel network is above the clearing temperature of the nematic LLC. We recently solved this challenge by a sort of kinetic control, in which the formation of the nematic LLC and its alignment by the action of a magnetic field is completed prior to the formation of the gel network [5,6]. As a result of the soft templating effect of the aligned nematic matrix, the gel fibers preferentially grow along

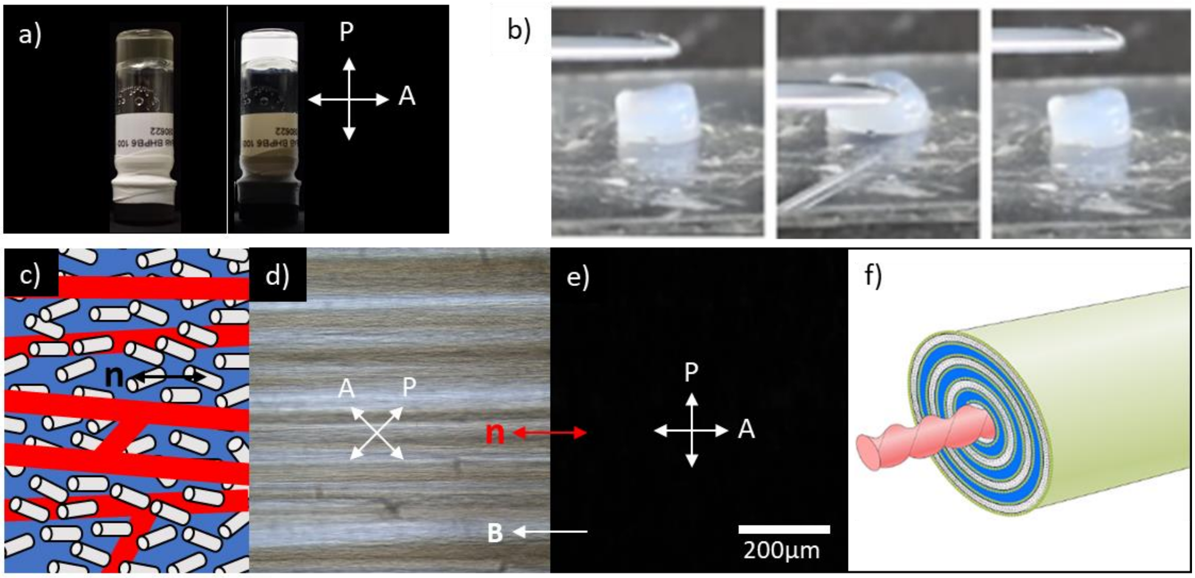

Figure 1. (a) Nematic lyotropic liquid crystal (LLC) gel outside (left) and between crossed polarizers (right). The anisotropic gel shows no macroscopic flow but strong optical birefringence. (b) Elastic response of a lamellar LLC gel. The gel returns to its original shape when the stress is released [3]. (c) Structure of an aligned nematic LLC gel: the rod-shaped micelles (grey) dispersed in water (blue) form a nematic phase with director **n**. The gel network (red) immobilizes the nematic phase. The fibers of the network preferentially run along **n** due to the soft-templating effect of the aligned nematic matrix. (d) Polarized optical microscope (POM) image between crossed polarizers of a nematic LLC gel sample with director **n** aligned along the external magnetic field direction **B**. (e) Same as (d) but with the crossed polarizers rotated 45° (extinction). (f) Schematic drawing of the synergistic structure in a lamellar LLC gel. The surfactant bilayers (green) bend around the gel fiber (red) to avoid energy-costly layer ends [7].

the nematic director (Fig. 1c–e). In lamellar LLC gels, however, an elaborated small-angle neutron scattering study [7] revealed the spontaneous formation of synergistic structures, in which the surfactant bilayers of the lamellar structure wrap around the relatively thick fibers of the gel network (Fig. 1f). Interestingly, these synergistic structures mimic similar schemes found in neural cells where axons are surrounded by lamellar myelin sheets.

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*frank.giesselmann@ipc.uni-stuttgart.de

Developing Biological Sensors with Oleosin-Stabilized Nematic Liquid Crystal Droplets

Axel Eijffius[1], Lawrence W. Honaker[1*], Constantinos V. Nikiforidis[1,2],
and Siddharth Deshpande[1*]

[1]Laboratory of Physical Chemistry and Soft Matter, Wageningen University & Research, 6708 WE Wageningen, Kingdom of the Netherlands
[2]Biobased Chemistry and Technology, Wageningen University & Research, 6708 WG Wageningen, Kingdom of the Netherlands

Harnessing the sensing potential of liquid crystals (LCs) into sensors to detect temperature [1], stresses [2], harmful gases [3], and other contaminants of interest [4–6] has fast become a topic of interest. One platform is using LCs in responsive aqueous emulsions of droplets and shells; however, owing to the extremely high interfacial tension between an LC and water, some amphiphilic interfacial stabilizer is necessary [7–8]. Most surfactants are inadequate for use due to them readily switching the alignment of the LC. The most commonly used stabilizer, poly(vinyl alcohol) (PVA), sufficiently stabilizes the LC–water interface without switching, but at the cost of a severe decrease in sensitivity of the interface to further amphiphiles, particularly large, bulky ones such as lipids [8–9]. An alternative is the use of an amphiphilic protein for stabilization, and one promising candidate can be found in oleosins [10], proteins derived from nut and seed oils (Figure 1(a)): these often are smaller in size than PVA while still showing both a strong amphiphilic character that could make them amenable to sensing and possibly better biocompatibility for eventual applications.

In this work, we investigate the use of these oleosins to stabilize liquid crystal droplets and their subsequent use for biological sensing. We find that the oleosins, at molar concentrations comparable to PVA [8], are capable of stabilizing the water–nematic LC interface over long durations of time (on the order of months). The oleosins readily localize at the LC–water interface without inducing an alignment switch, as seen in Figure 1(b-d), and the interface is responsive to the later introduction of amphiphiles (Figure 1(e)) at a greater sensitivity than we observe in droplets stabilized with PVA. In contrast, in a variety of chiral nematic LC phases as seen in Figure 1(f-g), an alignment change was directly induced by the oleosins at the same concentrations used to stabilize the non-chiral nematics. This could possibly be a consequence of residual lipids remaining from the oleosin purification process and the higher sensitivity of chiral nematic LCs to surfactants compared to non-chiral LCs; however, the sensitivity to oleosins is quite pronounced, serving as a basis for oleosin sensing. These findings can be further used in the development of sensing platforms, giving us clues to sensitivity and specificity improvements of LC-based sensors.

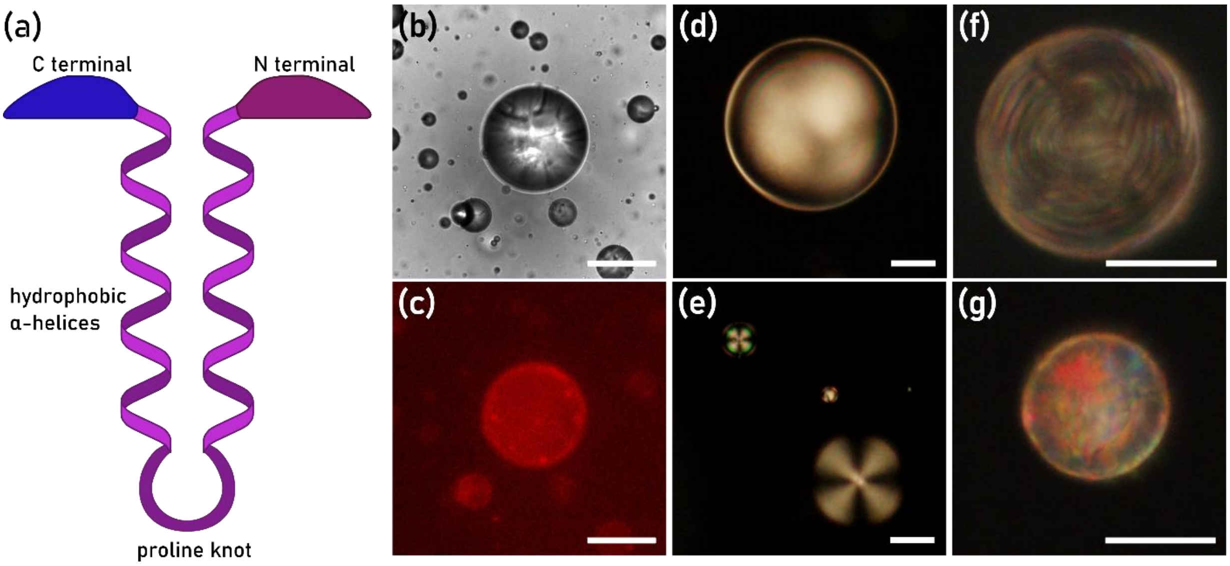

Figure 1. Oleosins have potential in sensing applications with liquid crystals. *(a) A schematic structure of an oleosin. Most oleosins have been found to consist of two hydrophilic "wings" flanking a hydrophobic core made from two parallel α-helices connected by a "proline knot". (b-c) In the common nematic liquid crystal host 5CB (4-cyano-4'-pentylbiphenyl), the oleosin in water does not switch the LC (b), but it localizes at the LC–water interface, which we can then visualize by epifluorescence microscopy using a fluorescent-tagged oleosin (c). (d-e) In simple reflection-mode polarizing optical microscopy, the oleosin-stabilized nematic LC shows a clearly unswitched texture (d), but the later addition of a surfactant (here, hexadecyltrimethylammonium bromide) causes the LC to adopt the "Maltese cross" pattern indicative of homeotropic anchoring (e). (f-g) In contrast, when we use both long-pitch chiral nematics (f) and short-pitch chiral nematics (g), the LC adopts a switched configuration. Scale bars in (b-f) 25 µm.*

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* Author for Correspondence: larry.honaker@wur.nl, siddharth.deshpande@wur.nl

Ferroelectric nematic liquid crystal for fast switching optical components

Yu Tung Hsiao[1], Inge Nys[1], and Kristiaan Neyts[1,*]

[1] Liquid Crystal and Photonics Group, ELIS Department, Ghent University, Ghent 9052, Belgium

The ferroelectric nematic phase (NFLC) is characterized by rod-shaped molecules in which the molecular dipoles orient in the same direction, which leads to a permanent polarization [1, 2]. This phase exhibits a strong interaction with electric fields and is therefore ideal for use in fast switching electro-optical devices [3]. Additionally, due to its non-centrosymmetric structure, NFLC materials have demonstrated unique properties for second harmonic generation applications [2, 4]. To make those applications possible, it is crucial to fully understand the electro-optical properties of these materials and to accurately control the alignment of the LC director.

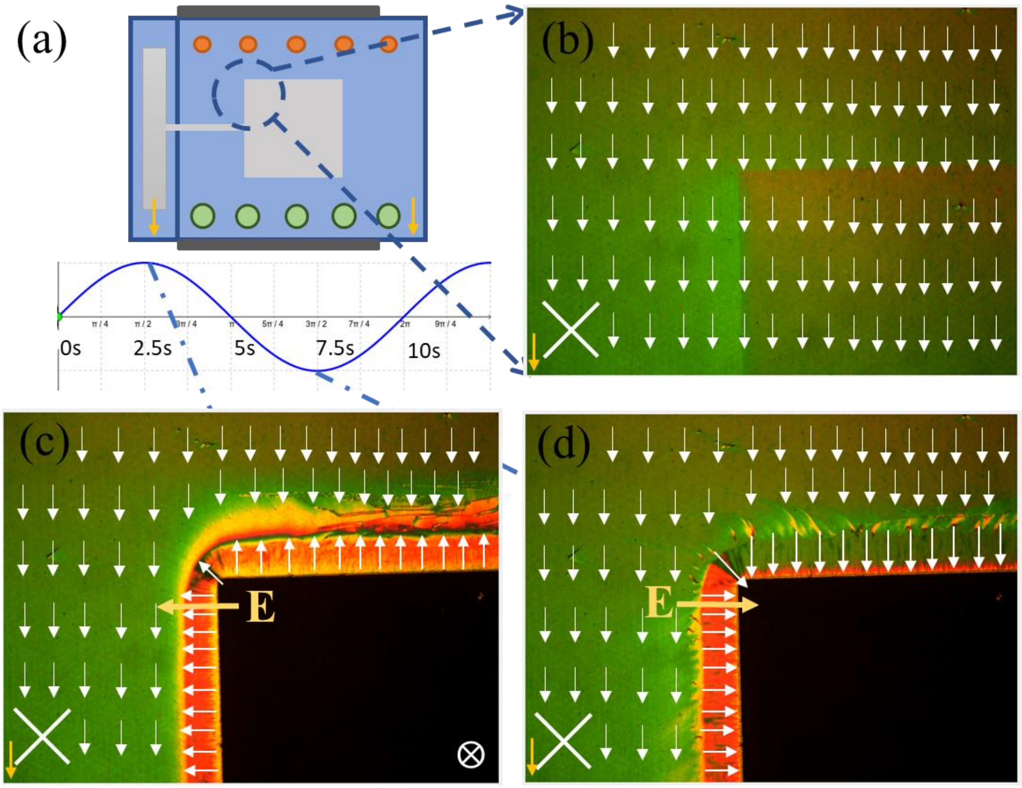

Figure 1. Electric-field induced effects in a uniformly aligned NFLC cell with thickness gradient. (a) schematic structure of the NFLC cell, showing rubbing direction and spacer spheres. (b) POM image without voltage application. POM images at the positive (c) and negative (d) polarity of the voltage (amplitude 3V) obtained during low frequency application (100 mHz)

In this work, electro-optic measurements are conducted on a wedge cell with parallel rubbing and variable thickness. The schematic of the cell is presented in Figure 1(a). In Figure, the yellow arrows indicate the rubbing direction. This cell is glued at two sides, with respectively a smaller (red) and larger (green) diameter of the spacers at the top and bottom in Figure 1 (a). After filling the cell with NFLC-RM734, polarizing optical microscopy observations are primarily analyzed in the NFLC phase, but some interesting phenomena also observed in the N phase and during the phase transition. To obtain (apart from a vertical electric field component) also a small, well-controlled in-plane electric field component, one substrate has a full ITO coating, and the opposite substrate has a square ITO electrode (Figure 1 (a)). A low frequency (100 mHz) voltage is applied to investigate the effect of the polarity of the (quasi-dc) field. The white arrows in Figure 1 (b-d) illustrate the estimated orientation of the permanent polarization in the NFLC phase. The application of an electric field causes a torque, leading to an expansion of domains with preferred polarity and a contraction of domains with opposing polarity. When a positive voltage is applied to the square electrode, domains separated by dark lines are observed and Pi-twisted domains are formed. Subsequently, when a negative voltage is applied, field-induced polarization reorientation is observed. Domain walls are erased, and larger regions of homogeneous polarization P are established. This property leads to asymmetric switching, depending on the polarity of the field, as illustrated by Figure 1(c) and 1(d).

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* Author for Correspondence: Kristiaan.neyts@ugent.be

The elastocaloric effect in main-chain liquid crystal elastomers of different crosslinking compositions

Marta Lavrič[1*], Andraž Rešetič[1], Dejvid Črešnar[1], Nikita Derets[1], Boštjan Zalar[1], Brigita Rožič[1], and Zdravko Kutnjak[1]

[1] Condensed Matter Physics Department, Jožef Stefan Institute, 1000 Ljubljana, Slovenia

Elastocaloric effect (eCE) in main-chain liquid crystal elastomers (LCE) is one of caloric effects, which are extensively studied to replace environmentally costly vapour-compresion refrigerants and, as soft condensed material, allowing the miniaturization of cooling devices. Caloric effects are reversible temperature changes observed in a broad range of materials upon the application and removal of an external field under adiabatic conditions. Depending on the nature of external field applied, they are categorized as electrocaloric, magnetocaloric and mechanocaloric.

The eCE in LCE is the inverse effect to thermomechanical and results in the change of temperature under the applied uniaxial stress field. It is expected to be a consequence of coupling between an external applied stress and the order parameter via the polymeric network [1]. The thermomechanical response can be controlled via three parameters, namely crosslinking concentration, external stress field during crosslinking and crosslinking temperature. Lower crosslinking densities gives sharper first order the nematic to paranematic/isotropic transition, while higher crosslinking densities make this transition broader supercritical [2].

The temperature changes of LCE samples with different concentration of crosslinkers were measured using a direct measurement technique in the vicinity of the I-N phase transition as a function of the external stress field and temperature.

The results show that the thermomechanical response from the nematic to paranematic/isotropic transition can be tuned from the supercritical regime towards the first-order regime, by decreasing the density of crosslinkers. In the latter case, the presence of latent heat additionally enhances the eCE at the phase transition from the disordered to the ordered phase [3], shown in Figure 1. We will show that the density of crosslinkers can tailor the magnitude of the eCE.

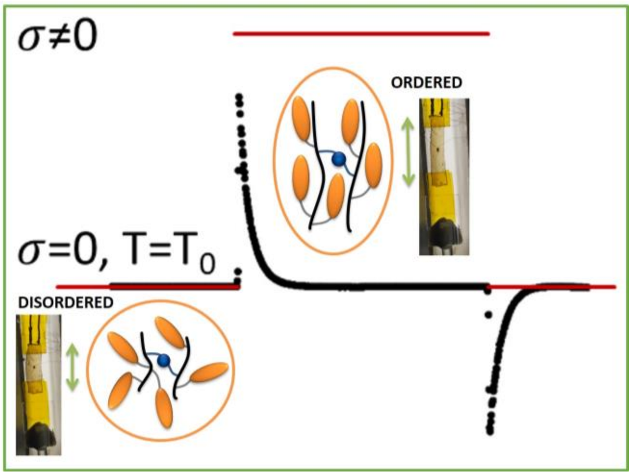

Figure 1: Measured elastocaloric temperature change (black line) in LCEs on applying and removing the external stress field (red line) on the same time scale. Mechanical stress σ induce phase transition from disordered to ordered state in LCE at constant ambient temperature.

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* Author for Correspondence: marta.lavric@ijs.si

Record Charge Mobility in the Nematic Phase of a Biaxial Nematogen

Matthias Lehmann[1]*, Nikolai Scheuring[1], Dharmendra Singh[2], João Figueirinhas[3], Pedro Sebastião[3], Carlos Cruz[3], Richard Mandle[4]

[1]Institute of Organic Chemistry, University of Würzburg, Würzburg 97074, Germany
[2]*Unité de Dynamique et Structure des Matériaux Moléculaires, ULCO, Calais, France*
[3]Centro de Física e Engenharia de Materiais Avançados, Lisbon 1049-001, Portugal.
[4]School of Physics and Astronomy, University of Leeds, Leeds LS29JT, Great Britain

In the search of a real biaxial nematic mesophase in the area of thermotropic, low molar mass mesogens a large number of molecules with high molecular biaxiality has been studied, with finally no widely accepted biaxial nematic material.[1] We recently designed a family of molecules **1** (Figure 1) which are roof-shaped with a rectangular basal area. The experimental over-all aspect ratio L : B : W is 10.73 : 3.16 : 1.23 and is therefore close to the optimum molecular biaxiality according to Straley (10 : 3.16 : 1).[2,3] It contains a long conjugated molecular axis, which can be easily aligned by a magnetic field, but also a strong dipole along the minor axis, which can be addressed by an electric field. One of these mesogens were comprehensively studied by X-ray scattering and NMR relaxometry and it was concluded that all results point at least to biaxial aggregates of several hundreds of biaxial molecules.[2] This prompted us to synthesize a library of molecules based on the lead structure **1**.

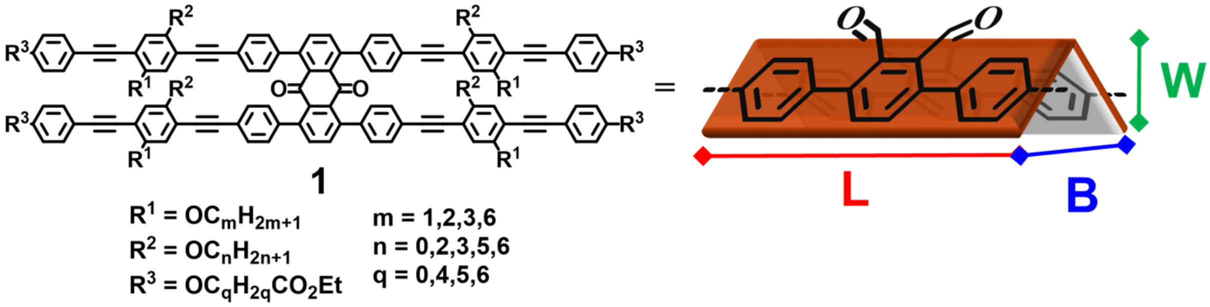

Figure 1. Biaxial, roof-shaped Nematogens with a rectangular basal area.

Here we will report about a unique substitution pattern for which lateral interdigitation is possible and which assists biaxial ordering of the closest neighbors. These results were confirmed by X-ray scattering and MD modelling. The compounds were further studied by simultaneous application of electric and magnetic fields. The results revealed the alignment of two molecular axes. However, a clear confirmation of a biaxial nematic phase has not been obtained so far owing to the missing macroscopic homeotropic biaxial alignment, although MD simulations predict a considerable biaxiality parameter. Just by chance we studied the charge carrier mobility of the material by the time-of-flight (ToF) method and surprisingly discovered the highest reported ToF electron mobility for a nematic phase in a LC cell with planar alignment layer in the range of 10^{-2} $cm^2V^{-1}s^{-1}$. Interestingly, there is a stepwise increase in the electron mobility on decreasing temperature. Rotation of the molecules in a uniaxial phase should clearly result in a higher resistance and lower charge carrier mobility at high temperatures. Thus, these outcomes at decreasing temperatures indicate a biaxial nature of the nematic phase.

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* Author for Correspondence: matthias.lehmann@uni-wuerzburg.de

Reconfiguration of Blue Phase Liquid Crystal by Photoalignment

Sunqian Liu[1], Inge Nys[1], and Kristiaan Neyts[1,*]

[1] Liquid Crystals and Photonics group, ELIS Department, Ghent University, Belgium

Soft material of blue phase liquid crystal (BP LC) exhibits sub-micrometer periodicity in three dimensions, which is well-known for its angle-dependent Bragg reflection in a certain wavelength range. The unit cell of BP LC is an arrangement of double twisted cylinders accompanied by intersecting disclinations in a simple cubic lattice for BPII and separated disclinations in a body-centered cubic lattice for BPI. The presence of a 3D photonic bandgap (for UV or visible light) makes BP LC an excellent candidate for a wide range of applications in photonic and display devices. Therefore, it is significant to explore how the BP crystal structure and alignment can be accurately controlled.

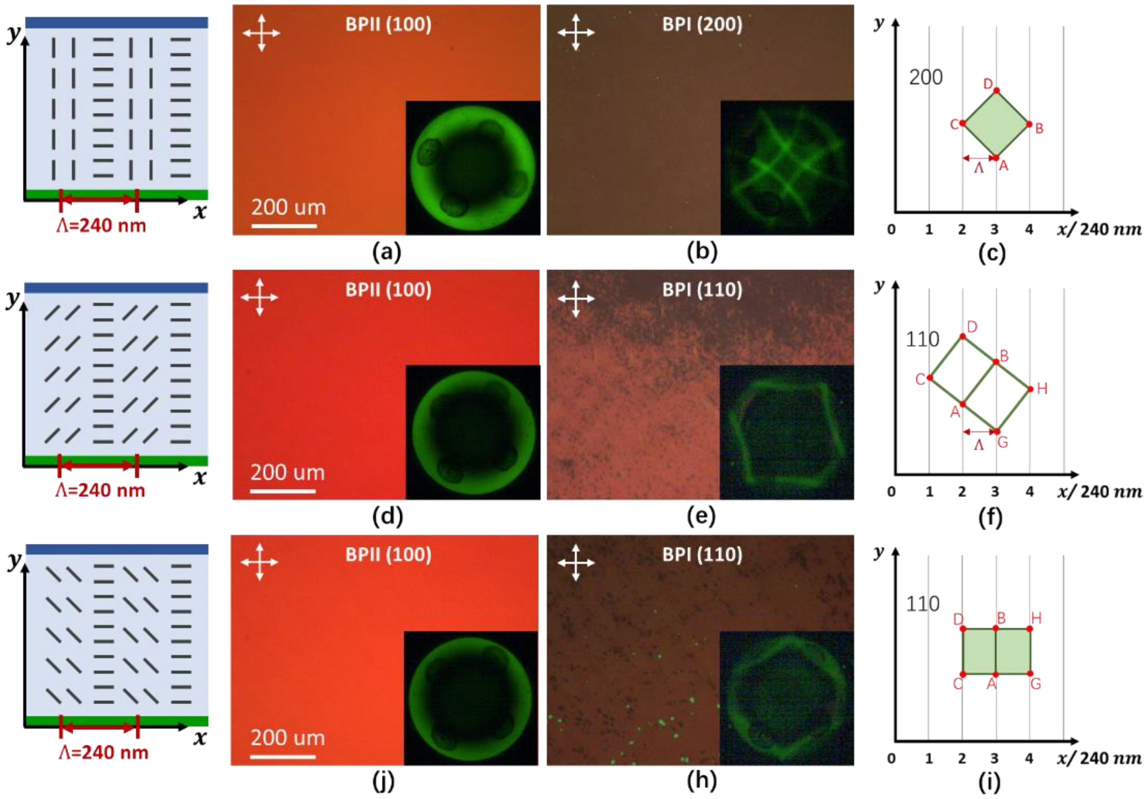

Figure 1. Optical reflections of BP LC in the photopattern with different boundary conditions [1].

We previously proposed a method of two-step photoalignment to obtain anchoring patterns with sub-micrometer periodicity at the confining substrates, compatible with the dimensions of the BP LC unit cell [2]. In this way, large areas with homogenous BPII (100) or (110) alignment have been obtained. In this work, we further explore how different boundary conditions affect the configuration of the BP LC crystal in the device (Figure 1). The cell thickness is 3 μm and the period of the anchoring pattern is 240 nm. For two-step photoalignment, we use the azo dye brilliant yellow (BY) as a photosensitive layer. In step I, linearly polarized light is used to obtain homogenous director alignment parallel to the y-aixs. Here, three patterns with homogenous director at 0°, 45° or -45° are obtained in step I. In step II, two light beams with equal polarizations and power, are incident under a large angle in step II to produce amplitude interference. The alignment induced by illumination step I remains in those regions where the amplitude in step II is small and changes to be parallel to the x-axis in those locations where the intensity of the second illumination step is large. The resulting alignment patterns are shown in the left column of Figure 1.

After the two illumination steps, the cell is filled at high temperature with BP LC (in the isotropic phase). Optical microscopy images are obtained under the crossed polarizers and Kossel diagrams are captured by inserting a Bertrand lens in the microscope. As shown in Figure 1(a), (d), (j), homogenous optical reflection in the red wavelength region demonstrates a large-scaled BPII domain with (100) orientation in these three anchoring patterns. In the BPI temperature range, three particular orientations with a deviating Kossel diagram are obtained for the three different anchoring patterns. This is the (200) orientation in Figure 1(b) and (110) in (e), (h). In our previous work, we have reported that the BPI unit cell can lose its cubic symmetry and reconfigure to match a square anchoring pattern [2]. Here, we assume 3 possible crystal orientations in which the corners of the elementary cube are spaced over the distance Λ in the x-direction. Thanks to this spacing, the BP crystal can fill space with periodic boundary conditions. The spacing in the y-direction of the lattice points offers a degree of freedom. The formation of the three different BPI configurations for the three different surface anchoring patterns should be related to a minimization of the free energy. This still needs to be verified (numerically) in future work. In any case, based on our experimental results it can be concluded that the BP LC configuration can be controlled by the boundary conditions in a accurate way, which shows a great potential to develop customized BP LC devices.

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* Author for Correspondence: Kristiaan.neyts@ugent.be

Control of Long-Range Gold Nanoparticles Networks in Liquid Crystals and their Topological Characterization

Nina Podoliak[1], Ingrid Membrillo Solis[2], Tristan Madeleine[2*], Giampaolo D'Alessandro[2]
Malgosia Kaczmarek[1], Tetiana Orlova[1,3] and Jacek Brodzki[2]
1. School of Physics and Astronomy, University of Southampton, Southampton, UK
2. School of Mathematical Sciences, University of Southampton, Southampton, UK
3. Infochemistry Scientific Center, ITMO University, Saint-Petersburg 197101, Russia

1. Complex networks of gold nanoparticles

Assembly of nanoparticles dispersed in a liquid crystal is a promising method for the large-scale nanomaterial fabrication. The ordering of liquid crystals can aid the assembly of nanoparticles, exploiting the layer structure or defect points and lines [1]. However, the resulting formations are often complex, permanent and there is very little structural control. Successful demonstration of long-range cellular networks was reported during phase transition in liquid crystals when doped gold nanoparticles functionalized with tailored mesogenic surfactants [2]. The cellular networks consist of regions with enriched particle content, forming at the interface between nematic and isotropic phases, at the clearing temperature. We show that such networks can also be realized experimentally with gold nanoparticles functionalized with commercially available an azo-ligand (GNPs) and using cooling rate and voltage, applied during phase transition, the networks are controllable and reversible. Such networks are an example of self-assembled large-sale soft material systems that are reconfigurable and can be refreshed.

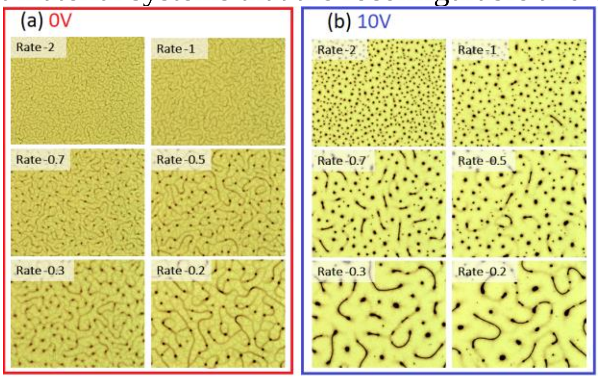

Figure 1. Optical microscope images of structural networks of GNPs in LC cell formed when the mixture is cooled at different cooling rate when (a) no voltage or (b) AC voltage at 10kHz, 10Volts rms applied to the cell. Cooling rate at °C/min specified at the corner of the image.

2. Cellular networks formation

The formation of structural networks was studied with azo-thiol ligand functionalized gold nanoparticles incorporated into liquid crystal 5CB at concentration of 3%wt. The material was heated to the isotropic state and when cooled to the nematic state, GNPs separate from the liquid crystal host and connect into complex cellular networks. Their structure can be controlled by varying cooling rate and applying external voltage (see Figure 1). The networks persist in a nematic state, however they slowly disintegrate into the liquid crystal bulk. They are fully reversible upon heating to the isotropic state, namely completely disappearing upon heating and holding a sample in the isotropic state. All the structures shown in Figure 1 were obtained in the same cell that was consecutively cooled and heated between isotropic and nematic states. The formation of different type of nanoparticle structures can be explained through the macroscopic ordering of the nematic host. In cells without alignment treatment of their surfaces, the textures, with randomly oriented domains, are observed in the absence of external voltage. When voltage is applied, the collective reorientation of liquid crystals, and their ordering, promotes the assembly of particles, expelled from the volume, leading to a rich tapestry of patterns, connected components and clusters, but without aggregation, presenting an interesting example of a complex, dynamic system.

3. Topological data analysis

To understand the process of GNP separation from the host into complex structures, we used topological data analysis methods. Over the last decade, persistent homology has become a popular data analytic tool that has been used in the structural characterisation of a variety of novel materials and an efficient tool to analyze complex dynamical systems using images [3,4]. The goal in persistent homology is to quantify topological features of the underlying shape of the data across different scales. We recorded the process of phase transition and analysed the video frame-by-frame with each frame converted into grey scale images and analysed using gradient analysis. The death of the topological features of degree 0, the connected components, correspond to the minimum distance between neighbouring networks. Figure 2 shows that the application of a voltage significantly increases the distance between the networks. Indeed, a high voltage creates small and isolated cluster-shaped networks while absence of voltage allows the creation of extended and intricate networks. Therefore, at similar cooling rates, the networks formed at high voltage are more isolated than those formed without applied voltage. At both voltages, figure 2 shows a decline in the distance between the networks in terms of the cooling rate. A high cooling rate induces a fast formation of networks forming a dense collection of many elongated, without voltage, or clustered, with voltage, networks. However, a slow cooling rate allows the merging of these networks, leading to fewer but larger networks and thus, more isolated.

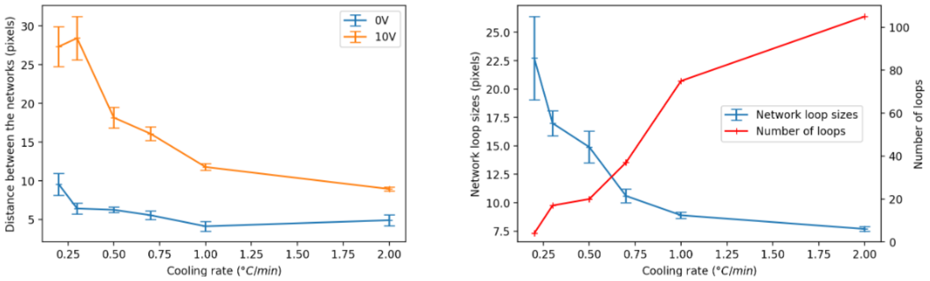

Figure 2. Evolution in terms of the cooling rate with and without voltage of: (a) the distance between the networks, (b) of the number and sizes of loops formed by the networks, no voltage applied

In conclusion, we show that azo-functionalized GNPs in a nematic host can serve as a flexible and reconfigurable test bed for the study of complex, reconfigurable networks. We also demonstrated that TDA is a powerful mathematical method to characterize such systems, effectively identify critical points during phase transition, fully characterizing their structure and describe the dynamics of their formation as well as disintegration into nematic host at different experimental conditions.

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*** Author for Correspondence: tm3u18@soton.ac.uk**

Numerical Modelling of Skyrmions in Blue Phase III

Matevž Marinčič[1,2*], Jaka Pišljar[1], Sharmistha Ghosh[3], Srikanth Turlapati[4], Nandiraju V. S. Rao[4], Miha Škarabot[1], Alenka Mertelj[1], Andrej Petelin[1], Andriy Nych[1,5], Anja Pusovnik[2], Igor Muševič[1,2] and Miha Ravnik[2,1]

[1] Condensed Matter Department, J. Stefan Institute, Ljubljana, Slovenia
[2] Faculty of Mathematics and Physics, University of Ljubljana, Ljubljana, Slovenia
[3] Department of Physics, University of Calcutta, Kolkata, India
[4] Chemistry Department, Assam University Silchar, Assam, India
[5] Department of Molecular Photoelectronics, Institute of Physics, Kyiv, Ukraine

We report on a mesoscopic Landau de Gennes numerical modelling of blue phase III (BPIII) – an amorphous liquid crystalline phase made of entangled skyrmions (or double twist cylinders) and topological defect lines [1]. By changing the initial conditions and geometry of the sample, the liquid crystal relaxes to a variety of stable or metastable structures. The amorphous BPIII structure is numerically stable and has the lowest total free energy in a narrow range of high temperature and high chirality, as shown in the calculated phase diagram. The numerical simulations provide insight into the detailed structures of these new material, which corresponds also to the experimental realisation of the BPIII, as the experimental optical microscopy images are in remarkable agreement with the optical simulations [1,2]. We developed a numerical algorithm to recognize and study the skyrmion filaments as the key constituents of the BPIII. We show the difference between the half-skyrmions which form in constricted thin planar cell geometry and the quarter-skyrmion filaments in thicker samples or in 3D bulk geometry. The distribution of the radial twist of the director relative to the distance to the skyrmion center shows a continuous span of values, generally corresponding to half-skyrmions in thin planar cell geometry and quarter-skyrmion filaments in thicker cells and in bulk.

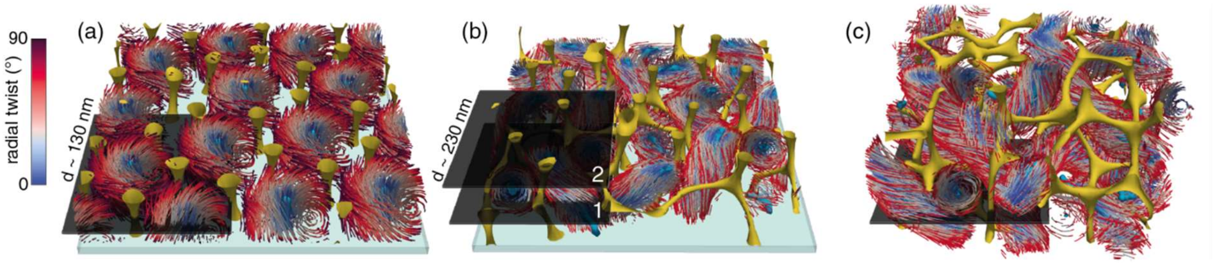

Figure 1. The BPIII skyrmion structures in thin planar cell (a), thick cell (b) and in bulk (c). The center of the skyrmions are shown in light blue. BPIII skyrmions are visualized using vector field lines representing the director field, colored according to the local radial twist (color bar) with respect to the center of the skyrmion. The disclination lines are shown in yellow. The bottom plate, where planar anchoring condition applies, is shown with light blue, whereas the top plate is omitted for clarity.

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* Author for Correspondence: matevz.marincic@fmf.uni-lj.si

Cell Instructive Polymers based on Liquid Crystals

Daniele Martella[1,2*], Marta Rojas,[1] Diederik S. Wiersma[1,2,3] and Camilla Parmeggiani[1,4]

[1]European Laboratory for Non Linear Spectroscopy, Sesto Fiorentino 50019, FI, Italy
[2]Istituto Nazionale di Ricerca Metrologica (INRiM), Torino 10135, TO, Italy
[3]Department of Physics and Astronomy, University of Florence, Sesto Fiorentino, 50019, FI, Italy
[4]Department of Chemistry “Ugo Schiff”, University of Florence, Sesto Fiorentino 50019, FI, Italy

Control of the collective cells organization and their correct differentiation are key steps to reproduce biological tissues *in vitro*. So far, many attempts to prepare polymeric scaffolds that mimic the biological environment have been done, trying to reproduce the mechanical properties or the extracellular matrix composition and topography. To date, cell differentiation protocols required scaffolds bearing micro/nanometric features or stimulated ones (by mechanical stretching or electric field). However, the complexity of these methodology strongly limits their wide application. A completely different approach, described in this communication, for the alignment and differentiation of several cell lines, exploits Liquid Crystalline (LC) polymers. Materials with anisotropic molecular structure and tunable rigidity have been prepared by photopolymerization of acrylate-based LCs and tested as support for cell growth (from human fibroblasts, C2C12 myoblasts and cardiomyocytes). We demonstrated LC polymers to present several advantages with respect to commercial scaffolds such as an improved adult-like dimensions and a more mature cell function of human induced pluripotent stem cell-derived cardiomyocytes (hiPSC-CMs) in a shorter time. [1] Furthermore, LC organization was demonstrated able to drive specific cells arrangements during fibroblast and myoblast cultures, as shown in Figure 1. Cell alignment was found to follow the nematic director thus demonstrating, for the first time, as the LC order inside the material can be translated to a living organism. [2,3] Eventually, myotube maturation has been investigated with electrophysiological studies showing as muscular fibres cultured on our LCs present better functional features with respect of those obtained on standard supports. [4]

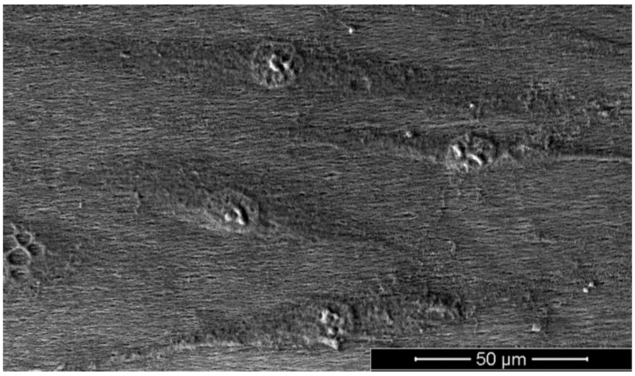

Figure 1. SEM image of aligned fibroblast on a LC scaffold

D. Martella aknowledge INRiM for financial support (Next-Generation Metrology project).

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* Author for Correspondence: martella@lens.unifi.it

Active matter state of a ferroelectric nematic liquid crystal

Marcell Tibor Máthé[1,2*], Hiroya Nishikawa[3], Fumito Araoka[3], Ágnes Buka[1], Antal Jákli[1,4,5],
Péter Salamon[1]

[1]Institute for Solid State Physics and Optics, Wigner Research Centre for Physics, P.O. Box 49,
Budapest H-1525, Hungary
[2]Eötvös Loránd University, P.O. Box 32, H-1518 Budapest, Hungary
[3]RIKEN Center for Emergent Matter Science, 2-1 Hirosawa, Wako, Saitama, 351-0198, Japan
[4]Materials Sciences Graduate Program and Advanced Materials and Liquid Crystal Institute, Kent State
University, Kent, Ohio 44242, USA
[5]Department of Physics, Kent State University, Kent, Ohio 44242, USA

Active matter systems, such as flocks of birds, bacterial colonies in biology, or active membranes, are composed of constituent components that consume energy and drive the system to exhibit complex behaviour. The movement of self-propelled particles that comprise artificial active matter is often a result of chemical reactions, as seen in Janus colloids [1]. However, a major challenge with such systems is their limited controllability over particle properties like velocity.

We present studies of a new state of two-dimensional active matter, where the constituent components are droplets of ferroelectric nematics. In the liquid bridge geometry, we observed that an electric field-induced surface instability results in the fragmentation of droplets [2]. This process gives rise to the creation of distinct "particles". Moreover, these particles show a high degree of mobility at a specific frequency and voltage range. We reveal the relationship between the emerging motion and the shape of the particles, and we make a comparison to other active matter systems.

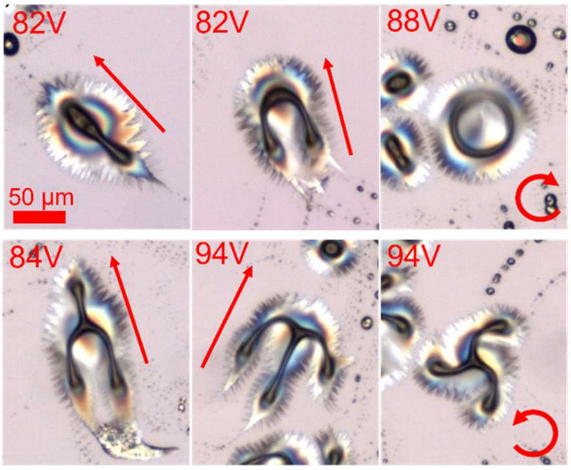

Figure 1. *Snapshots of the moving ferroelectric nematic droplets in the active state.*

Acknowledgement: This work was supported by NSF DMR 2210083 and by NKFIH FK142643.

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* Author for Correspondence: mathe.marcell.tibor@wigner.hu

Photonics and optomechanics of core-shell mesogenic-metallic particles

Alfredo Mazzulla[1*], Nicola Pellizzi[2], Pasquale Pagliusi[1,3] and Gabriella Cipparrone[3]

[1] CNR Nanotec - Institute of Nanotechnology, S.S. Cosenza, 87036 Rende (CS), Italy,
[2] Department of Physics, Politecnico di Milano, Piazza Leonardo da Vinci 32, 20133, Milano, Italy,
[3] Department of Physics, University of Calabria, Ponte P. Bucci 31B, 87036 Rende (CS), Italy

Core-shell architecture provides unique features to microparticles (MPs) by accurately selecting the employed materials. MPs with a mesogenic core and a metallic shell of gold nanoparticles (NPs) have been realized. The core is obtained by UV induced polymerization of reactive mesogens droplets in a chloroauric acid aqueous solution, whilst gold nanoparticles precipitation happens at the same time, covering the MPs surface. The MPs optical properties are modified by the gold shell, in the Bragg onion resonator condition when a chiral core is utilized, improving the laser emission stability compared to the MPs without shell. The proposed strategy, due to both the method and the versatility of the materials, suggests a new route to realize microdevices with wide control in term of intensity, polarization, generation [1].

The development of efficient micromachines is a challenge for applied and fundamental research. Light is a worthy mean to remotely displace micro-objects by inducing forces and torques. Rotational dynamics of core-shell MPs having ellipsoidal shape and nematic core is studied, and in particular a peculiar synchronous spin-orbital motion when the MPs are irradiated by a simple Gaussian beam. The observed effects originate from the coupling of the metallic NPs' optical response and the core anisotropies. The rotation performances strongly improve when trapping wavelength lie inside the plasmonic resonance range. In that case, spin kinetic energy achieves values two orders of magnitude larger than the one obtained from the bare MPs. The proposed approach bears important insights for design optimization in the MPs light driven motion, giving benefits to applications in microfluidics, microrheology, and micromachining that imply rotational dynamics [2].

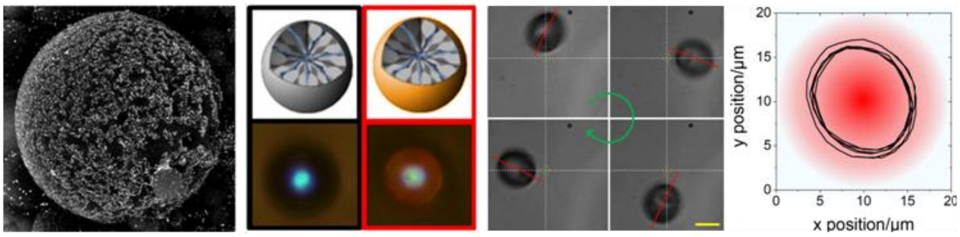

Figure 1. From left: SEM image of a core-shell MP; Internal scheme and optical image of a bare and a core-shell MP; Frames sequence of spin-orbital motion of a nematic MP; Orbital motion tracing of the MP's baricenter

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* Author for Correspondence: alfredo.mazzulla@fis.unical.it

Flow-mediated mechano-electric phenomena in ferroelectric nematic liquid crystals

Peter Medle Rupnik[1,2*], Nerea Sebastián[1], Luka Cmok[1], and Alenka Mertelj[1]

[1]J. Stefan Institute, Ljubljana, Slovenia
[2] Faculty of Mathematics and Physics, University of Ljubljana, Slovenia

The recently discovered ferroelectric nematic liquid crystals (FENLC) are liquids, that exhibit both long-range orientational ordering of the elongated constituents and ordering of the constituents' dipolar moments[1,2,3]. One important aspect of these materials is how external mechanical action affects their electric polarization structure. In the viscous regime, an applied stress in FNLC will induce material flow. The combination of fluidity and large polarization values is expected to result in novel mechano-electric phenomena.

Here we report on the observed effects of flow on the polarization structures of the FENLC confined to layers. In a special case, we demonstrate how electric current can be induced by mechanically deforming the FENLC sample. FENLC was filled into a custom-made deformable liquid crystal cell with in-plane electrodes attached to the bottom glass plate. The complex material flow induced by sample deformation caused changes in the polydomain structure of FENLC and also carried the defect structures across the slit between the bottom electrodes (Figure 1). Consequently, mechanically generated electric current can be then detected by means of adequate pick-up circuits.

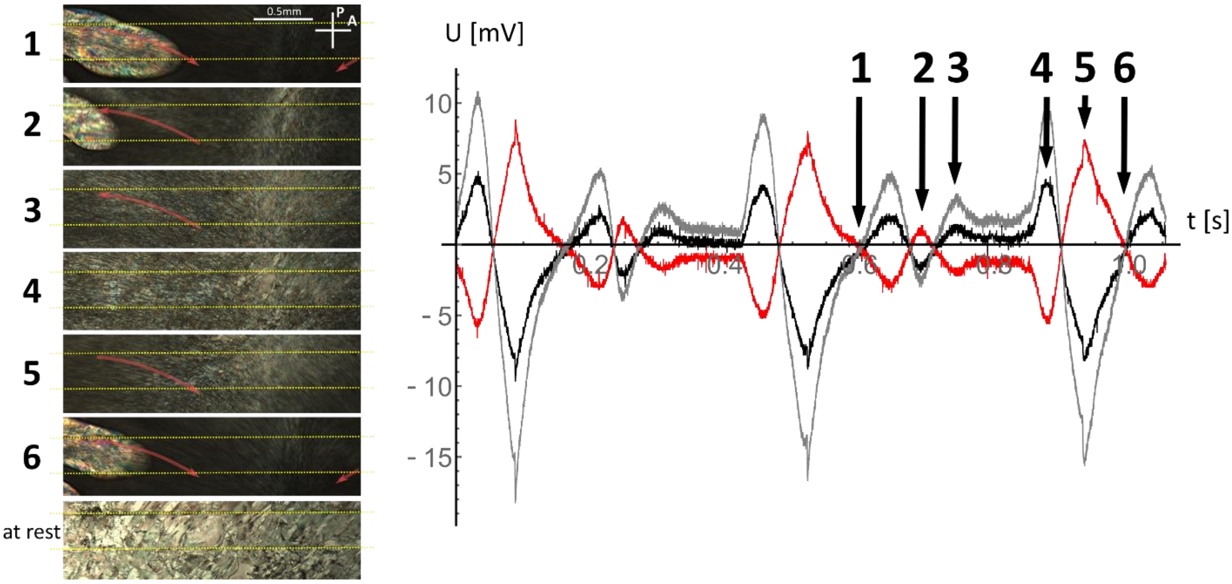

Figure 1. Electric signals from the two electrodes (red and black) and the difference (grey) correspond to the POM images on the left. Red arrows correspond to the approximate flow orientation as the sample is subjected to mechanical deformations.

Acknowledgments:

The study was funded from the European Union's Horizon 2020 research and innovation programme by the project MAGNELIQ under grant agreement no 899285 and by the Slovenian Research Agency (research core funding no. P1-0192).

Ferroelectric nematic liquid crystal material used in this work was supplied by Merck Electronics KGaA.

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* Author for Correspondence: peter.medle.rupnik@ijs.si

Liquid Crystal Optical Microcavity with built-in Uniform Lying Helix as a platform for tunable one-dimensional photonic potential with spin-orbit interaction

Marcin Muszyński[1], Przemysław Oliwa[1], Eva Oton[2], Rafał Mazur[2], Przemysław Morawiak[2], Wiktor Piecek[2], Przemysław Kula[3], Barbara Piętka[1] and Jacek Szczytko[1*]

[1] Institute of Experimental Physics, Faculty of Physics, University of Warsaw, ul. Pasteura 5, 02-093 Warsaw, Poland
[2] Institute of Applied Physics, Military University of Technology, ul. Gen. S. Kaliskiego 2, 00-908, Warsaw, Poland
[3]Institute of Chemistry, Military University of Technology, ul. Gen. S. Kaliskiego 2, 00-908, Warsaw, Poland

Photonic crystals with optical anisotropy possess degrees of freedom related to the polarization of light and specified directions allowed by dispersion. The coupling of photonic modes of different parity – which is possible due to birefringence – may introduce chirality [1]. If an additional periodic potential is present, the resulting photonic band gaps and eigenstates of light inherit the polazation properties of the whole system [2].

Here, we demonstrate a dye-doped optical microcavity with a built-in uniform lying helix (ULH) structure that was induced in a chiral nematic liquid crystal matrix. As a result of the presence of ULH, a one-dimensional self-organized periodic lattice of refractive index modulation was formed. We observed two separate photonic band structures with orthogonal linear polarizations of light (Figures a, b). The inclination of the helix with respect to the plane of the cavity additionally induced a Rashba-Dresselhaus spin-orbit interaction for light, which couples these two bands together. As a result of the spin-orbit coupling, new chiral states with distinct circular polarizations are formed (Figure c).

The proposed platform has several unique technological advantages. A self-assembled one-dimensional well-oriented photonic potential is formed over a macroscopic area. The period of ULH can be tuned by external electric field, thickness of the cavity and temperature. In addition, due to doping the structure with light emitters, the system can exhibit non-linear effects like the laser light emission from photonic bands, which opens new possibilities for the photonic control of light-emitting devices.

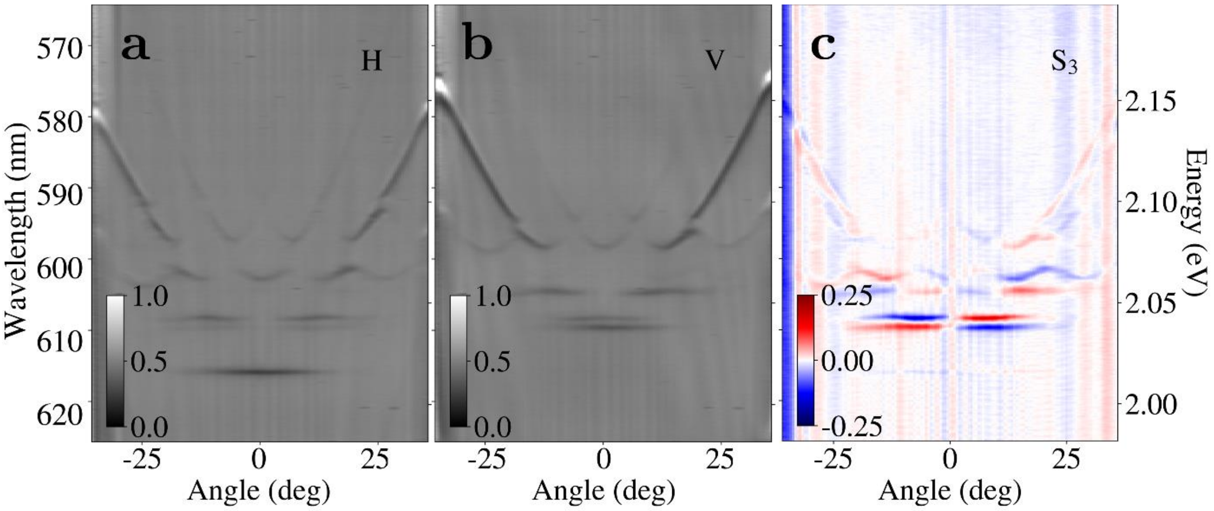

Figure 1. Dispersion relation measured for the orthogonal linear (a) horizontal H and (b) vertical V polarization of the detected light. (c) The Stokes parameter S3 shows circularly polarized states of light caused by Rashba-Dresselhaus spin-orbit coupling.

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jacek.szczytko@fuw.edu.pl

Liquid Crystal Magnets: Fine-Tuning Nanoscale Properties and Dynamics

Hajnalka Nádasi[1*], Alexey Eremin[1], Melvin Küster[2], Frank Ludwig[2], Nerea Sebastián[3], Alenka Mertelj[3], Darja Lisjak[4] and Patricija H. Boštjančič[5]

[1]Institute of Physics, Otto von Guericke University, Magdeburg, Germany
[2] Institute for Electrical Measurement Science and Fundamental Electrical Engineering and LENA, TU Braunschweig, Braunschweig, Germany
[3] Jošef Stefan Institute, Ljubljana, Slovenia

Since the discovery of liquid magnets [1] ferromagnetic liquid crystal suspensions of anisotropic scandium-doped barium hexaferrite (BaHF) platelets in anisotropic and isotropic hosts deliver astonishing new insights into the dynamical nature of this system. The properties of these materials are based on interplay of electrostatic and magnetic dipolar interactions as well as steric repulsion. To balance the strong magnetic dipolar and steric interactions, the anionic surfactant (DBSA) provides a duly powerful electrostatic stabilisation to avoid aggregation of the platelets in an isotropic medium [2]. We explore magnetic dynamics, optical properties and self-assembly of these liquid magnets employing optical imaging and magnetic susceptometry in oscillating and rotating fields. We found that self-assembly-driven collective modes can be induced or suppressed by fine-tuning the electrostatic interactions [3, 4].

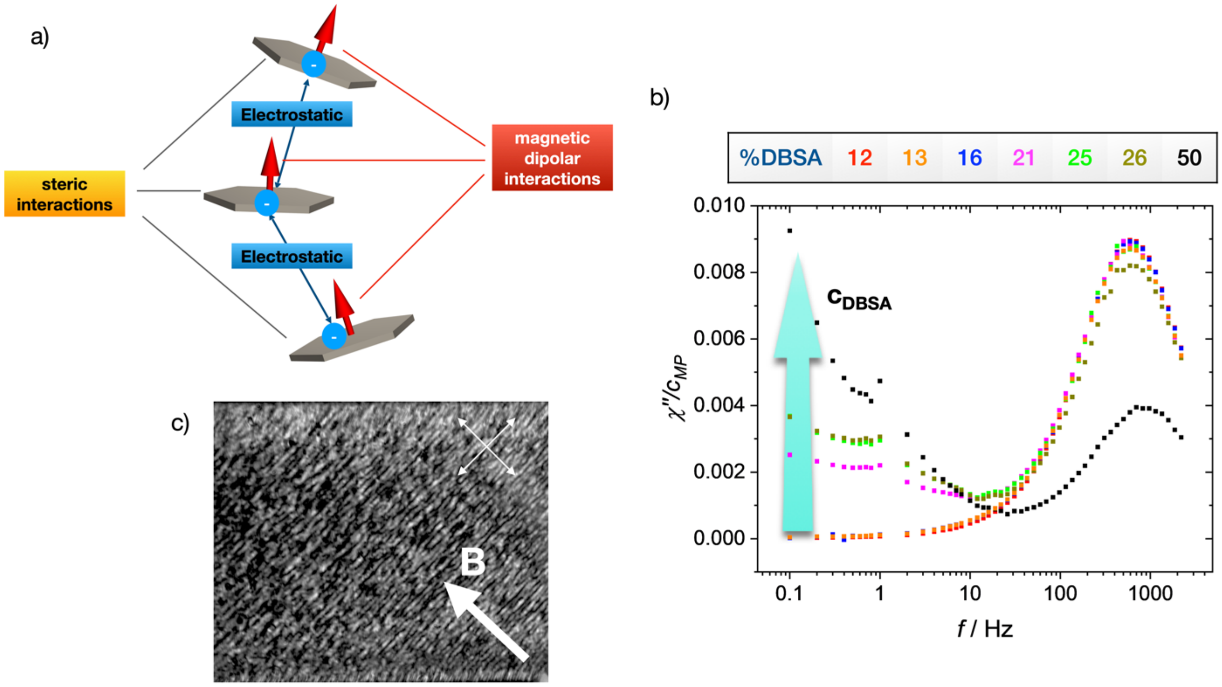

Figure 1. a) Interactions involved in the stabilisation of nanoplatelet suspensions; b) Development of low-frequency modes in ac susceptibility spectra on increasing DBSA concentration; c) Periodic stripe patterns forming in an AC magnetic field in the ferromagnetic nematic state ($B = 0.5$ mT, $f = 100$ Hz).

Here we explore how a variation of the surfactant concentration can drive self-assembly and give rise to multimodal structures in the AC susceptibility spectra even at low magnetic particle concentration. We attribute the emergence of low-frequency dynamics to the correlation of the platelets and reversible cluster formation, which is enhanced by increasing the DBSA concentration due to the growing ionic strength in the suspension affecting the nanoscale properties of fluid magnets and their microstructure. Additionally, we study the dynamics of the optical response and the formation of magnetohydrodynamic patterns in the oscillating and rotating magnetic fields using optical microscopy. The observations are discussed in the light of magnetic dynamics and orientational order.

Acknowledgement: This research has been supported by the German Science Foundation (NA 1668/1-1 and LU 800/7-1) and the Slovenian Research Agency (P1- 0192, P2-0089, J1-2459, PR-08973 and PR-08415).

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* Author for Correspondence: hajnalka.nadasi@ovgu.de

Cholesteric Shells: Two-Dimensional Blue Fog and Finite Quasicrystals

G.Negro[1],
L.N Carenza[2], G. Gonnella[3], D. Marenduzzo[1], E. Orlandini[4]

[1]SUPA, School of Physics and Astronomy, University of Edinburgh, Peter Guthrie Tait Road, Edinburgh, EH9 3FD, UK
[2]Instituut-Lorentz, Universiteit Leiden, P.O. Box 9506, 2300 RA Leiden, Netherlands
[3] Dipartimento di Fisica, Università degli studi di Bari and INFN, Sezione di Bari, Via Amendola 173, 70126 Bari, Italy
[4] Dipartimento di Fisica e Astronomia, Università di Padova, 35131 Padova, Italy

We study the phase behavior of a quasi-two-dimensional cholesteric liquid crystal shells using three dimensional extensive Lattice Boltzmann simulations. We characterise the topological phases arising close to the isotropic-cholesteric transition, and show that they differ in a fundamental way from those observed on a flat geometry. For spherical shells, we discover two types of quasi-two-dimensional topological phases: finite quasicrystals and amorphous structures, both made up of mixtures of polygonal tessellations of half-skyrmions (see Fig. 1). These structures generically emerge instead of regular double twist lattices because of geometric frustration, which disallows a regular hexagonal tiling of curved space [1].

For ellipsoidal shells, defects in the tesselation couple to local curvature, and according to the shell size they either migrate to the poles or distribute uniformly on the surface [2].

For toroidal shells, the variations in the local curvature of the surface stabilises heterogeneous phases where cholesteric or isotropic patterns coexist with hexagonal lattices of half-skyrmions [2]. Quasicrystals and amorphous and heterogeneous structures could be sought experimentally by self-assembling cholesteric shells on the surface of emulsion droplets.

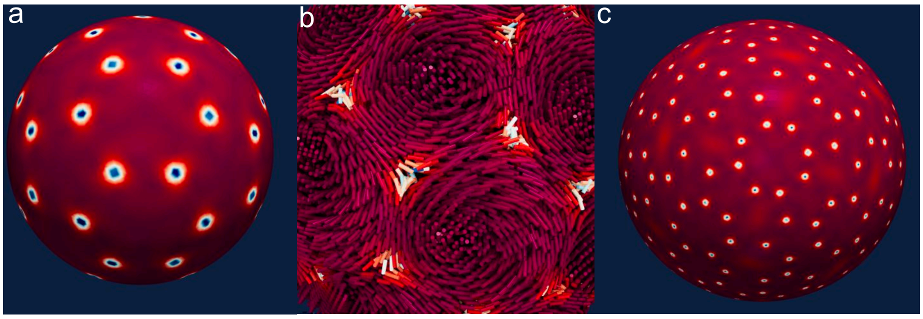

Figure 1: **Spherical Shell configurations.** (a) Color plot of to the isotropy parameter c_s of the Westin metrix [3] (blue regions define defect positions ($\boldsymbol{Q} \sim 0$), while red ones are ordered ($\boldsymbol{Q} \neq 0$)), for a finite quasi-crystal configuration. Panel (b) shows the director field pattern of two half-skyrmions and nine $-1/2$ defects defining a pentagon and a hexagon in panel (a). Panel (c) shows an amorphous configuration.

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Periodic and Multi-Step Photoalignment to obtain 3D Liquid Crystal Structures

Inge Nys[1], Brecht Berteloot[1], Sunqian Liu[1], Peter Ropac[2], Miha Ravnik[2], Kristiaan Neyts[1]

[1]Liquid Crystals and Photonics group, ELIS Department, Ghent University, Belgium
[2]Faculty of Mathematics and Physics, University of Ljubljana, Slovenia

Photoalignment enables to define a preferred alignment, without realizing contact, by illuminating a photosensitive film with blue or UV light. We use azo dye compounds as photo-sensitive materials such as brilliant yellow, SD1, PAAD22 or ATA2. Illumination of linearly polarized light orients the LC director orientation perpendicular to the plane of polarization. Periodic photoalignment can be realized by illuminating a photosensitive layer with a structured laser beam, either by interference between two coherent laser beams [1,2], or by projecting the light reflected from the pixels of a spatial light modulator onto the substrate [3,4]. The interference method makes it possible to achieve structures with period below 200 nm, which is useful for the alignment of blue phase LC [5]. The HDTV spatial light modulator has more than 2 million pixels and each pixel can define a particular azimuthal angle, which makes it possible to design complicated patterns, such as defect grids or patterns with variable periodicity [3,4,6,7].

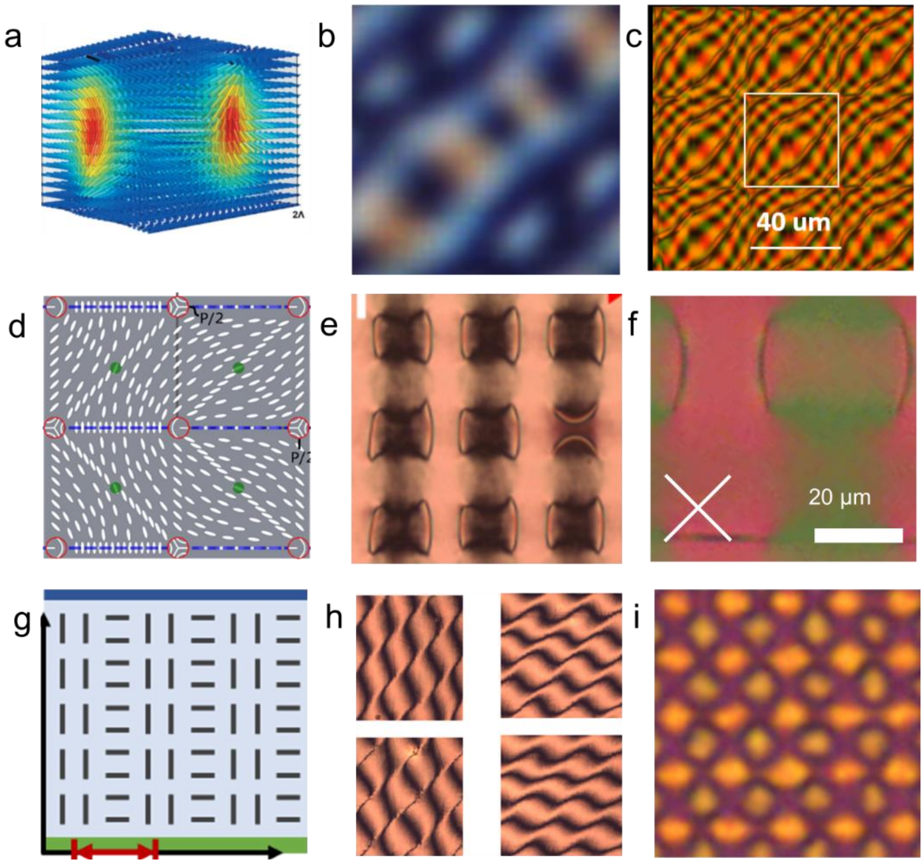

Figure 1. Nematic liquid structures created by periodic photoalignment. Top row: one substrate with rotating alignment along *x*, one substrate with rotating alignment along *y*. Middle row: one substrate photoaligned with a pattern containing +/- ½ defects, one substrate with rubbed alignment (horizontal). Bottom row: substrates photoaligned after cell assembly, by using a sequence of illumination steps.

Using different alignment patterns at the top and bottom substrates of a LC device can lead to complex three-dimensional structures, when the elastic energy in a nematic LC is minimized. Fig. 1a shows the 3D simulated configuration of the nematic LC director, obtained by minimizing the elastic energy. Fig. 1b shows the transmission through crossed polarizers of this structure [1,2]. Fig. 1c shows a similar structure with variable periodicity, resulting in an electrically switchable grating that can contain many diffraction orders (scattering appearance) [3]. In these structures the director has a region in the volume where it is perpendicular to the substrates, although the photoalignment at the surfaces is everywhere parallel to the substrates. The obtained transmission images match very well with numerical simulations of the transmission.

When a substrate is photoaligned with a pattern containing +1/2 and -1/2 defects, as illustrated in in Fig. 1d and the other substrate is rubbed, interesting patterns occur, as illustrated in Fig. 1e and 1f. The defects on the surfaces are connected one-by-one through disclination lines in the bulk of the LC. The curvature of the disclination lines allows to estimate the free energy per unit length [4]. Combining the same photoaligned defect grid with a homeotropic top substrate, results in different disclination interconnections in the bulk [7].

The third row in Fig. 1 illustrates the principle of photoalignment by sequential illumination. Fig. 1g illustrates the pattern that is obtained after homogeneous vertical alignment in the first step, and an interference pattern with varying intensity to obtain horizontal alignment in the second step. Fig. 1h and Fig. 1i show the transmission characteristics for nematic liquid crystal layers obtained after multiple illumination steps with the spatial light modulator setup [5,6]. A new algorithm to determine the resulting azimuthal angle after multiple illumination steps will be introduced.

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* Author for Correspondence: kristiaan.neyts@ugent.be

Nano-clustering over phase transitions in diastereomerically-stabilized ferroelectric nematics

Hiroya Nishikawa[1*], Koki Sano[1,2], Saburo Kurihara[3], Go Watanabe[3], Atsuko Nihonyanagi[1], Barun Dhara[1], and Fumito Araoka[1*]

[1] RIKEN Center for Emergent Matter Science (CEMS), 2-1 Hirosawa, Wako, Saitama 351-0198, Japan
[2] JST PRESTO, 4-1-8 Honcho, Kawaguchi, Saitama 332-0012, Japan
[3] Department of Physics, School of Science, Kitasato University, 1-15-1 Kitasato, Sagamihara, Kanagawa 252-0373, Japan

Introduction

A new state of liquid crystal (LC) state, ferroelectric nematic ($\mathrm{N_F}$) phase is a hot topic of great interest from fundamental and practical aspects because of its outstanding characteristics such as ferroelectric responses, large polarization density ($> 4\ \mu\mathrm{C/cm^2}$) and NLO. So far, there have been developed many $\mathrm{N_F}$LCs based on the archetypal models a.k.a. RM734, DIO, and UUQU-4-N [1,2,3], for which the importance of molecular parameters (e.g. dipole moment, oblique dipole angle, and geometrical aspect ratio) has been discussed. Nevertheless, the mechanism behind the stability and phase transition regarding the $\mathrm{N_F}$ phase have remained unclear. We herein introduce a $\mathrm{N_F}$LC engineering concept based on the dipole equivalents, i.e. DIO diastereomer, ^{trans}C3DIO and ^{cis}C3DIO for controlling the $\mathrm{N_F}$ phase transition, and discuss the effect of smectic cybotactic cluster formation in the $\mathrm{N_F}$ phase of the DIO-based diastereomeric mixture system with the aid of X-ray diffraction and molecular dynamics (MD) simulation.

Experiments

We prepared LC blends of ^{trans}C3DIO (**1**) and ^{cis}C3DIO (**2**) (Fig. 1a, synthesized in our laboratory) with various concentrations in chloroform. To characterize LC behavior of them, polarized optical microscopy (POM), differential scanning calorimetry (DSC), and wide/small-angle X-ray diffraction/scattering (WAXD, SAXS) were performed. To investigate polarization behavior, dielectric relaxation spectroscopy, *P-E* hysteresis measurement and SHG investigation were carried out. To discuss molecular packing in the $\mathrm{N_F}$ phase for **1**/**2** (*dr* = 50/50), DFT calculation and MD simulation were employed.

Results and discussion

POM images of the $^{trans/cis}$DIO mixture (**1**/**2**) are shown in Fig. 1b. With increasing the concentration of **2**, that is, in the order of *dr* = 100/0 → 70/30 → 60/40, three types of phase transitions: isotropic liquid (IL) → N → mesophase (M) →$\mathrm{N_F}$, IL → N → $\mathrm{N_F}$, IL → $\mathrm{N_F}$ were observed (Figure 1b). These phase transitions were identified by combining POM, DSC and XRD results. In the case of **1**/**2** with *dr* = 100/0, the characteristic polar defects were observed in the inhomogeneous texture from the M to $\mathrm{N_F}$ phase. By increasing the doping level of **2**, the M phase was vanished whereas further adding **2** eventually caused direct phase transition from IL to $\mathrm{N_F}$ phase. Thus, we expected that the introduction of **2** had exerted influence on controlling of the phase transitions in the **1**/**2** system.

To investigate this effect in detail, we performed 2D XRD measurement under a magnetic field (**B**). Figures 1c and 1d are the WAXS and SAXD profiles, respectively, in the $\mathrm{N_F}$ phase for **1**/**2** with *dr* = 70/30. At the small angle region at the equator (**n** || **B**) (Fig. 1c), a distinct dumbbellshaped diffraction pattern (p_1) emerged while a halo due to π–π interaction on the meridian (**n** ⊥ **B**) was observed (Fig. 1d). For the peak p_1, with considering the following three general tips, the smectic cybotactic cluster with the polar order may mediate in the N_F phase for **1**/**2** system.

(i) The skewed peaks are reflected from the normal cybotaxis, in which SmC-like stratification exists within the clusters floating in the N phase. [4]
(ii) The high order peaks owing to the anomalously large correlation length in the cybotactic clusters are observed in the N phase in a rigid lath molecule. [5]
(iii) The large correlation length can be due to the polar order $\langle P_1 \rangle$ in the N_F phase. [6]

We further investiegted the relationship between anisotropic growth of the clusters and *dr* value in the N_F phase using analitical method proposed by Francescangeli *et al.* [3] In the range of $dr < 65/35$, the cluster swole parpendicular to the molecular director with decreasing temperature (case A in Fig. 1e). On sharp contrast, tendency of longitudinal growth was observed over the entire N_F phase range in the range of $dr \geq 65/35$ (case B in Fig. 1e). By combining POM, DSC, and XRD data, we found that the phase transition sequence was dichotomized [i.e. IL → N → (M) → N_F or IL → N_F] at $dr \geq 65/35$, where the cluster anisotropy changed significantly. Hence, the result cleary demonstrated that the anisotropic growth of the polar cluster floating in the N_F phase affect in the phase sequence in **1**/**2** system. Futher details will be discussed.

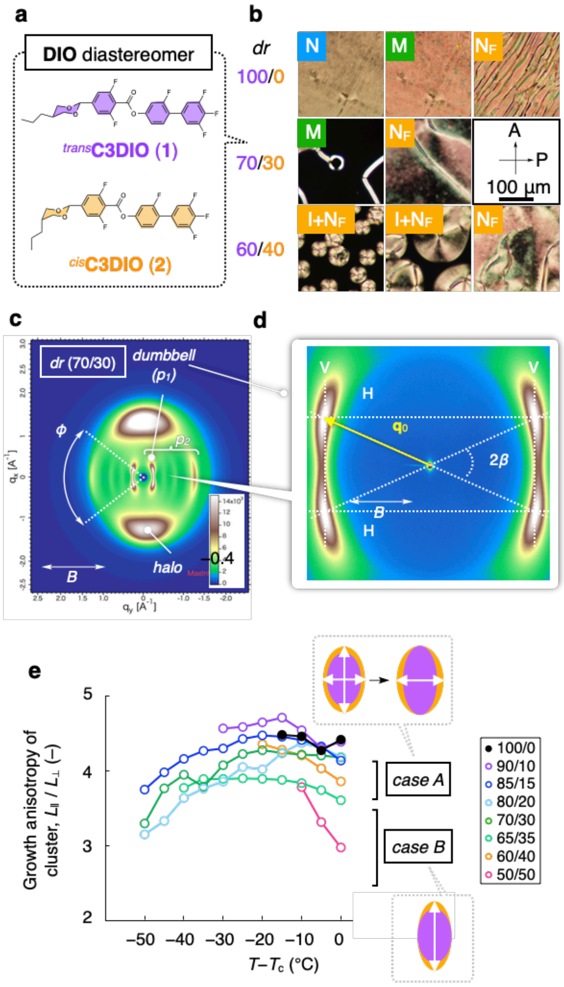

Figure 1. (a) Chemical structures of ^{trans}C3DIO (**1**) and ^{cis}C3DIO (**2**). (b) Polarized optical microscope images of **1**/**2** system with different diastereomeric ratio (dr = 100/0, 70/30 and 60/40). Wide- (c) and small-angle (d) X-ray diffraction profile for **1**/**2** with dr = 70/30 (**B**: magnetic field). (e) The relationship between growth anisotropy of cluster and *dr*, and its temperature dependence. Inset cartoon depicts the two variations (case A and case B) of the anisotropic growth of the cybotactic cluster in the N_F phase.

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* Author for Correspondence: hiroya.nishikawa@riken.jp; fumito.araoka@riken.jp

Synchrotron GISAXS study of the effect of thickness on Smectic A liquid crystal topological defects

Jean de Dieu Niyonzima[1*], Haïfa Jeridi[1], L. Essaoui[1], C. Tosarelli[1], I. Trimaille[1], Alina Vlad[2], Alessandro Coati[2], S. Royer[1], Doru Constantin[3], D. Babonneau, Michel Goldmann[1], Yves Garreau[2], Bernard Croset[1,] and Emmanuelle Lacaze[1*]

[1]Sorbonne Université, CNRS, Institut des Nanosciences de Paris, INSP, F-75005 Paris, France.
[2]Synchrotron Soleil, BP 48, L'Orme des Merisiers, 91192 Gif sur Yvette, France.
[3]Institut Charles Sadron (ICS) 23, rue du Lœss 67034 Strasbourg.
[4]Université de Poitiers, CNRS, Institut P'.

The breaking of continuous symmetry in ordered systems results in topological defects, which are the places where the order melts[1]. Due to their ubiquitous nature and versatility, the topological defects have been of a great interest in different research area such as cosmology and condensed matter physics. They are important in the determination of dynamic and static properties of the material that host them [2]. Smectic A liquid crystal topological defects have been shown to be able to attract, trap and orient nanoparticle into different networks in their defect cores [3]. It is thus necessary to progress on the intimate structure and possible assembly of topological defects. The smectic liquid crystal thin films between antagonistic anchorings at the two interfaces (substrate and air) constitute an ideal platform to produce and study topological defects.

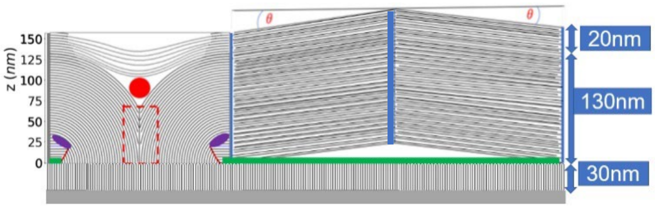

Figure 1. internal structure of the smectic hemicylinder with all topological defects.

It has been shown that 8CB smectic A liquid crystal thin films confined between homeotropic anchoring (at air) and uniform planar anchoring (on rubbed PVA substrate) are distorted into an array of parallel stripes that can be observed using optical microscopy and studied using synchrotron Grazing Incident Small Angle X-ray Scattering (GISAXS) thanks to the lamellar structure of the smectic A 8CB [4]. Using GISAXS measurements we have recently developed a model of the stripes (figure 1). Each stripe is a deformed flattened hemicylinder (Figure 1 shows two neighboring quarters of cylinder from two neighboring hemicylinders on the left side and the flattened central part on the right side). One stripe is formed at its two edges by smectic layers rotating around its axis including dislocations (in violet on Figure 1) and disclinations (in red on Figure 1). There are perpendicular layers in its lower part in contact with the substrate. In the central part of the hemicylinder a grain boundary (in green on Figure 1) joins the perpendicular layer close to the substrate and almost flat layers, slightly tilted by an angle 2θ, of the order of 2° (figure 1). This tilt leads to a chevron structure in the center of the hemicylinder (in-blue on Figure 1).

We show that the tilt angle 2θ decreases linearly as a function of the smectic film thickness. In order to understand this decreasing, we have studied the evolution of the quarters of cylinders when the thickness increases. The results show that the disclination area (on top of the red core shown on figure 1) evolves as the thickness changes whereas the area of dislocation remains unchanged. This demonstrates that the tilt decreasing is induced by the increasing of the disclination area. This confirms the interpretation related to the formation of the central chevron structure that occurs due to a mismatch of interlayer spacing between the dislocation area and the central layers that do not exist between the disclination area and the central layers. This finally suggests that most of the topological defects evidenced in one given 8CB stripes are finally induced by the small film thickness that would induce a particularly strong bending of the layers.

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* Author for Correspondence: *jean-de-dieu.niyonzima@insp.upmc.fr,
emmanuelle.lacaze@insp.jussieu.fr

Topological Detection for Revealing Individual and Collective Skyrmion Transformations in Their Dynamic Assemblies

Tetiana Orlova[1,2*], Ingrid Membrillo Solis[3], Hayley R.O. Sohn[4], Giampaolo D'Alessandro[3],
Ivan I. Smalyukh[4], Jacek Brodzki[3], and Malgosia Kaczmarek[2]

[1] Infochemistry Scientific Center, ITMO University, Saint-Petersburg 197101, Russia
[2] Physics and Astronomy, University of Southampton, Southampton SO17 1BJ, UK
[3] Mathematical Sciences, University of Southampton, Southampton SO17 1BJ, UK
[4] Department of Physics, University of Colorado, Boulder, CO, USA

Topological Data Analysis (TDA) is a recent and quickly growing field providing new topological and geometric analytical tools to disclose underlying features of complex systems reflected in data point clouds for different characteristics in Euclidean or more general metric spaces [1]. The widely used method to compute topological features is the persistence homology, numerous examples of the use of which can be found in biology, medicine, chemistry, physics, and material science [2-4]. Recent approach involves TDA embedding in the machine learning technique for identifying a reduced set of topological features which can be used as an input into a faster and simpler computation pipeline [5,6].

However, the interpretation of the topological features to extract various characteristics of physical systems remains a major issue. Moreover, only a few attempts have been made to analyze complex structures at several hierarchical levels, with, perhaps, the best example of TDA applied to the analysis of zebrafish skin patterns, which allowed quantification of the underlying dynamics of pigment cells [7].

Liquid crystals are a unique soft matter system offering a wide range of self-assembled soliton structures, which in turn can exhibit collective behavior similar to many-body systems of solid particles [8]. This invites researchers to use such systems as test cases for development of TDA methods, especially in the field of hierarchical, multi-level system analysis.

In our study, we consider dynamic assemblies of electrically driven skyrmion-like structures in chiral liquid crystals as a model active system that demonstrates both collective motion and individual shape transformations of soft quasiparticles during their movement [9,10]. Real data available for TDA analysis are only experimental video recordings of toron motion, that is, in other words, sets of 2D distributions of the recorded light intensity after light passes through a system of two 90-degree crossed polarizers and an LC sample between them.

Firstly, we apply the geometric approach to obtain the distance matrices and to perform the principal component analysis. The latter reveals the attractor-like dynamics in the phase space of the principal components for experimentally obtained physical data characterizing the behavior of a two-dimensional toron quasi-crystal. However, this doesn't allow one to access the changes that occur to the individual soft quasi-particles. We introduce a new topological descriptor, the so-called Psi function, that helps to reveal variations in the 2D shape of localized structures when analyzing the same set of real experimental data. Since changes in the observed shape are associated with the variations of the 3D orientational distribution of molecular field, topological data analysis will open access to another level of the hierarchy by involving the simulation of the director field and the corresponding cross-polarized optical images.

To sum up, we believe that the presented approach paves the way to a multiscale analysis of structural changes and behavior dynamics of active many-body systems, composed of time- and space- evolving elementary units, and, of course, this technique can be extended to hierarchically organized living and non-living systems.

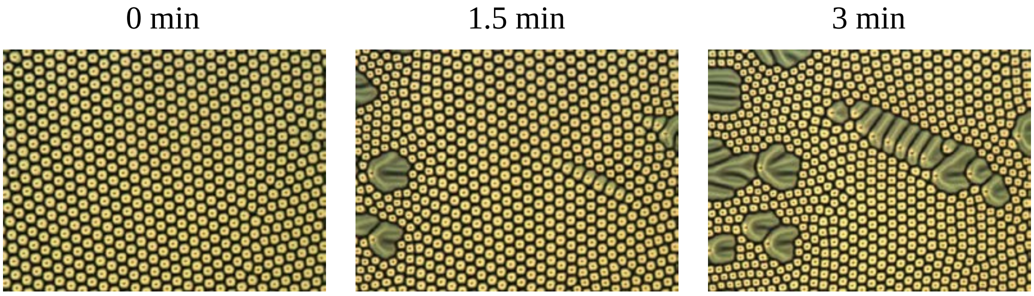
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Рис.1. Snapshots from the experimental video recording of an electrically induced collective motion of a toron quasi-crystal while some soft quasi-particles undergo individual shape transformations from the cholesteric spherulites into fingers.

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* Author for Correspondence: torlova@itmo.ru

Electrostatic Effects and the Origin of Ferroelectric Ordering in Polar Nematics

Mikhail A. Osipov[1*] and Maxim V. Gorkunov[2]

[1]Department of Mathematics and Statistics, University of Strathclyde, Glasgow G1 1XH, UK
[2] FSRC “Crystallography and Photonics”, Moscow119333, Russia

Recently, ferroelectric ordering has been discovered in a few nematic materials composed of strongly polar molecules with several large dipoles located throughout the molecule [1,2]. Both the ferroelectric splay phase [1] and the homogeneous phase [2] have been observed, and the more recent results are reviewed in [3]. At the same time, the origin of ferroelectric ordering is far from being fully clarified. In particular, the ordering seems to be sensitive to the cell geometry, type of the electrodes and other boundary conditions.

We show that these effects are at least partially determined by long-range electrostatic interactions and boundary conditions, and study the role of electrostatic energy, orientation of the polarization and the electric field in the cell, boundary conditions at grounded or floating electrodes and the effect of internal electric field created by polarization charges. We demonstrate how in some cases the spontaneous polarization can be strongly suppressed.

It has been shown both theoretically [4] and by computer simulations [5] that molecular interactions driven by single dipoles modulated by ellipsoidal cores do not promote dipolar ordering. At the same time, atomistic simulations reveal the formation of polar clusters [2,6]. We consider a combination of electrostatic interaction between several tilted molecular dipoles and the induction interaction between the dipoles and the benzene rings which may promote ferroelectric ordering. Both mean-field theory and the two-particle cluster theory are discussed.

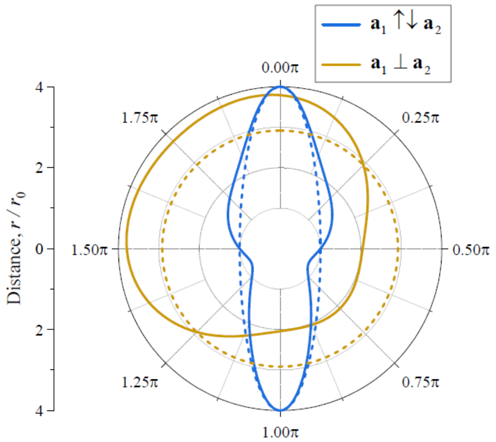

Figure 1. The range of modified Gay-Berne potential with (solid) and without (dashed) polar contribution.

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* Author for Correspondence: m.osipov@strath.ac.uk

Contrasting quadratic and quartic elastic theories for Chromonics

Silvia Paparini[1*], Epifanio G. Virga[1]
[1] Department of Mathematics, University of Pavia, Pavia 2710, PV, Italy

Chromonic liquid crystals (CLCs) are lyotropic materials which are attracting growing interest for their adaptability to living systems. To describe their elastic properties, the classical Oseen-Frank theory, which posits a stored energy *quadratic* in the gradient of the director filed **n**, requires anomalously small twist constants and (comparatively) large saddle-splay constants, so large as to violate one of Ericksen's inequalities, which guarantee that the Oseen-Frank energy density is bounded below. While such a violation does not prevent the existence and stability of equilibrium distortions in problems with fixed geometric confinement, the study of free-boundary problems for droplets has revealed a number of paradoxical consequences. A CLC droplet tactoidal in shape is predicted by the classical theory to be unstable against shape changes: it would split indefinitely in smaller tactoids while the total energy plummets to negative infinity. To overcome these difficulties, we propose a novel elastic theory that extends for chromonics the classical Oseen-Frank stored energy by adding a *quartic* twist term. The total energy of droplets is bounded below in the quartic twist theory, so that the known paradoxes are ruled out. The quartic term introduces a phenomenological length a in the theory; this affects the equilibrium of chromonics confined within capillary tubes.

Available experimental data for chromonics confined to cylindrical cavities with degenerate planar anchoring on their lateral boundary can be explained equally well by both competing theories. The aim of this talk is to identify means to differentiate these theories both qualitatively and quantitatively on the basis of the different structures they predict when CLCs are either confined to fixed spherical cavities with homeotropic anchoring or allowed to occupy the whole 3D Euclidean space.

There are quantitative differences, related to the phenomenological length a, which may be experimentally accessible, and also qualitative ones, perhaps more elusive, but equally telling.

* Author for Correspondence: s.paparini@unipv.it

Hyperbolic metamaterials for enhancement spontaneous emission engineering

Karol Sielezin, Malwina Liszewska[1], Bogusław Budner[1], Maciej Urbańczyk,
Rafał Kowerdziej, Janusz Parka*
Military University of Technology,
Institute of Applied Physics, [1]Institute of Optoelectronics, Warsaw, Poland

Hyperbolic metamaterials (HMMs) represent a new class of plasmonic materials, that exhibit hyperbolic dispersion when they interact effectively with incident radiation. These unique properties are crucial for many advanced photonic applications of HMMs, e.g.: in ultra-high resolution microscopy, imaging systems, sensing and cloaking, as well as thermal and spontaneous emission engineering [1-3]. Interestingly, nanostructured metamaterials with hyperbolic dispersion can cause tremendous increase of the PDOS (Photonic Density of States) [4]. Large PDOS of HMMs is an enhanced decay rate of quantum emitters in HMM stack. Importantly, this enhancement can be expressed by the Purcell factor which strongly depends on PDOS.

There are two types of HMMs: Type I HMMs ($\varepsilon_{xx} = \varepsilon_{yy} > 0$, $\varepsilon_{zz} < 0$) and Type II HMMs ($\varepsilon_{xx} = \varepsilon_{yy} < 0$, $\varepsilon_{zz} > 0$). While the PDOS for an ideal and homogeneous HMM diverges, the finite feature sizes imposed by practical constraints limits the highest **k** vector length $\mathbf{k}_{\max}$, which in turn makes the PDOS finite. As a result, an enhancement in the spontaneous emission of an emitters placed in the vicinity of HMM is observed. This leads to a broadband Purcell effects and this gives the possibility to control gain/absorption in tunable hyperbolic metamaterials. PDOS is a subject to formalism and the principles of quantum mechanics, which means the discretization of possible assumed energy values with a certain number of available states [1,4]. The PDOS, like its counterpart for electrons, is very important in the design of advanced electronic and photonic devices that use resonant quantum phenomena. An emitter located within the HMM structure has more decay channels in accordance with the Fermi's golden rule, which enhances its spontaneous emission. Therefore, placing a dipole near the HMM structure will result in spontaneous emission or its enhancement, which is stimulated by Resonant Energy Transfer (RET) between the generated Localized Surface Plasmon Resonance (LSPR) [4].

In this work results of different unit stacks cell structures ware simulated and experimentally checked. By changing the number of unit cell, as well changing the fill fraction, is possible to have a narrowband reflectance as switchable material in VIS and NIR. Ag/SiO_2 and Al/HfO_2 metamaterials in the NIR and MIR range were numericaly simulated and compared with experimental data of the Purcell factor for a dipole (Rhodamine and LC dye) placed in the top vicinity of a multilayer HMM structure. In this metastructures a hyperbolic Type II isofrequency dispersion have been observed. We showed that the value of F_P is strongly related to the orientation of the dipole with respect to the HMM stack. The Purcell factor for the manufactured transducer was measured using Surface Enhancement Raman Spectroscopy (SERS) method. Such layered plasmonic systems are ideal candidates for use in advanced and multifunctional nanophotonic platforms.

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*corresponding author, e-mail: janusz.parka@wat.edu.pl

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Quasi-Uniform Nematic Fields

Andrea Pedrini[1*], Epifanio Virga[1]

[1] Dipartimento di Matematica, Università di Pavia, Via Ferrata 5, 27100 Pavia, Italy

The local average orientation of the elongated molecules that constitute a liquid crystal is usually driven by their interactions and intrinsic geometry. For example, chiral or bent components favor an ordered state with twist or bend, respectively, while straight elongated components with steric interactions produce a nematic field which is uniformly oriented in space. Whenever such local tendencies cannot be globally accommodated in the entire space, or plane, or finite domain, a geometric frustration arises, and defects are produced in the liquid crystal texture.

Here we study ways for relieving frustration in a liquid crystal confined to a flat, two-dimensional space, by following a completely geometric approach, with no reference to any energetic consideration. In particular, we envision *quasi-uniform distortions* as a viable geometric mechanism for frustration relief. Such distortions, first presented in [1], extend the notion of uniformity given in [2]: they are defined by the property of having the elastic fundamental measures of splay, twist, bend and octupolar splay (the latter called biaxial-splay in [3]) in constant ratios to one another, instead of being constant as for uniform distortions.

After providing a set of compatibility conditions for quasi-uniform distortions to exist in the entire space, we restrict our study to the planar case. We prove that the only non-trivial quasi-uniform distortions capable of filling the entire plane have field lines consisting in logarithmic *spirals*.

We then restrict the domain where the liquid crystal is confined and allow for the existence of defects. We provide the explicit construction of two families of planar quasi-uniform distortions (Figure 1): one is defined in a half-plane, the other outside a circle. Quasi-uniform distortions in a half-plane are plenty, even if they all are, in a generic sense, asymptotically spirals.

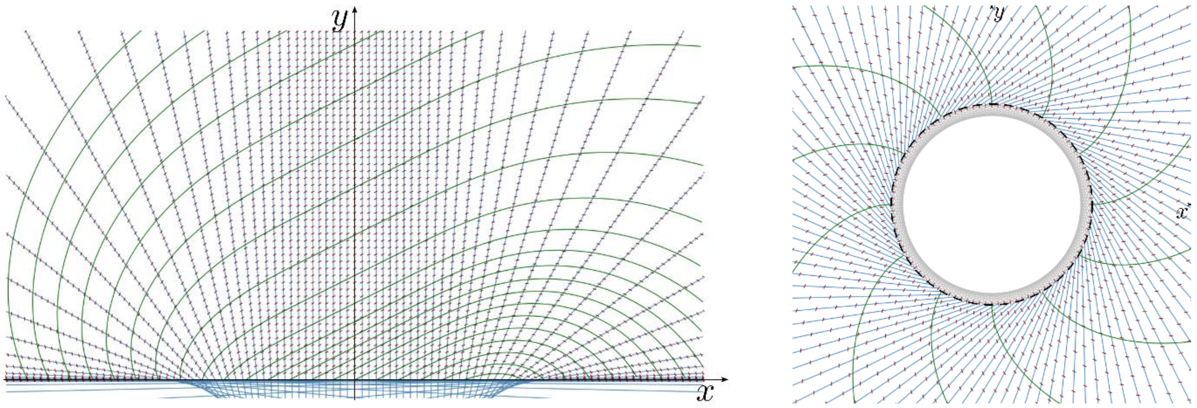

Figure 1. Examples of quasi-uniform distortion in the plane.

Finally, if time permits, we shall address the question of how to define uniformity and quasi-uniformity for nematic fields on a curved surface, extending the definition given in [4], which is based on intrinsic measures of distortions, oblivious to the way molecules interact in the ambient three-dimesional space.

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* Author for Correspondence: andrea.pedrini@unipv.it

Folds and tangles of dislocation loops in cholesterics

Pawel Pieranski[1*], Maria Helena Godinho[2]

[1]Laboratoire de Physique des Solides, Université Paris-Saclay, Orsay, France
[2] i3N/CENIMAT, NOVA University Lisbon, Caparica, Portugal

When a cholesteric is confined by capillarity between crossed cylindrical mica sheets [1,2,3], the Grandjean-Cano dislocation lines are expected to have shapes of individual concentric circles.

The pattern in Figure 1a is more complex because here the concentric lines are connected by radial segments made of crossing dislocation pairs. This pattern was generated by compression of the cylinder/cylinder gap that triggered serial nucleation of loops connected by dislocation pairs into **folded superloops**.

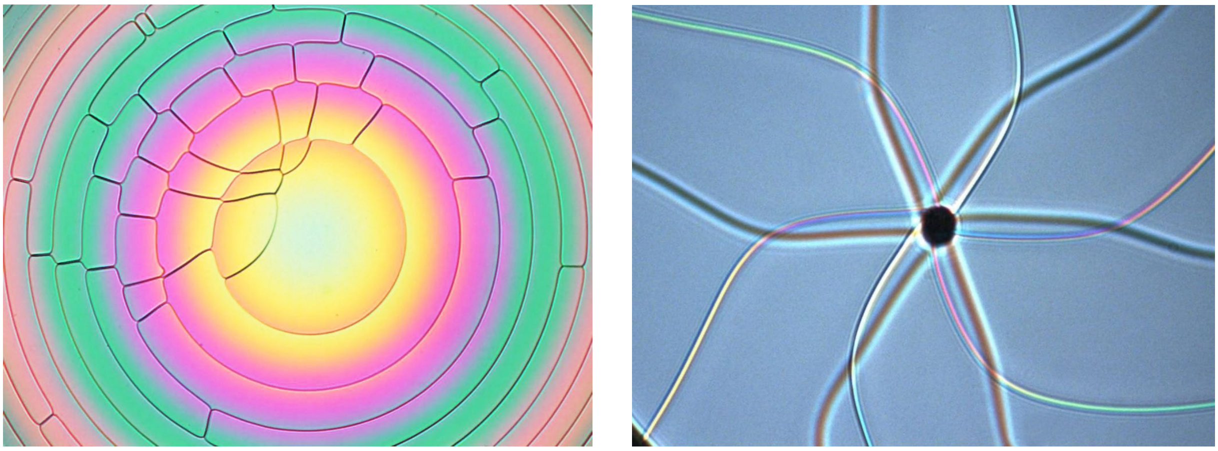

Figure 1.Patterns of dislocations in cholesteric droplets confined between crossed cylindrical mica sheets: a) Folded superloops generated by compression. b) Helical tangle of dislocations generated by extension.

The pattern in Figure 2 is made of twelve dislocation lines connected to the central node. Six of them are thin (sharp, in focus) and the other six are thick (fuzzy, out of focus) because the two sets they are situated at two different levels. This pattern corresponds to a **helical tangle** of six dislocations [1] wound up by extension of the cylinder/cylinder gap.

In our talk we will discuss the experimental and theoretical issues raised by these two typical experiments. In particular, using as the generic example a tangle of two dislocations, we will introduce the new concept of **topological metadefects** resulting from symmetry breaking.

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* Author for Correspondence: pawel.pieranski@u-psud.fr

Observation of helical self-assembly in cyclic triphosphazene-based columnar liquid crystals bearing chiral mesogenic units

Shruti Rani,[a] Vidhika Punjani,[a] Santosh Prasad Gupta,[b] Madhu Babu Kanakala,[c] C. V. Yelamaggad *[c] and Santanu Kumar Pal, *[a]

[a] Department of Chemical Sciences, Indian Institute of Science Education and Research (IISER) Mohali, Punjab, 140306, India

[b] Department of Physics, Patna University, Patna, 800005, India

[c] Centre for Nano and Soft Matter Sciences, Bengaluru, 560013, India

Nowadays, intensive research has focused on the design and synthesis of function-integrated smart materials resulting from the spontaneous self-assembly of appropriately chosen functional molecules. Working in this direction, we have synthesized a new series of non-conventional, chiral columnar liquid crystals (Col LCs), where the cyclotriphosphazene core is surrounded by cholesterol-based Schiff base dimeric units. Cholesterol, which is covalently bound to the two-ring Schiff base core via a flexible spacer of varying length and parity, has been premeditatedly incorporated to induce handedness in the Col fluid macrostructure.1,2 These investigations, using a number of complementary techniques, clearly reveal the influence of the length of the spacer, rather than the parity, on the symmetries of 2D lattices resulting from the intrinsic Col assemblies of the synthesized compounds. The different Col assemblies were further confirmed through detailed electron density mapping and small-angle/wide-angle X-ray scattering (SAXS/WAXS) studies. As conceived, bulky cholesterol, which can induce molecular chirality, directs the molecular assemblies in a helical manner in individual columns.3 The handedness (helicity) of the Col LCs has been confirmed via temperature-dependent chiroptical measurements where the intensity of the peak in the circular dichroism (CD) spectra increases with a decrease in temperature, implying that the core–core correlation within the columns and, thus, the proximity of the chromophores varies with the temperature.4,5 Notably, upon exposure to hydrochloric acid (HCl) these novel materials exhibit fluorescence ‘‘turn-on’’ characteristics2 in their solid (as synthesized) state that can be visualized instantly by the naked eye where the color change occurs with a low detection limit of 5.6 μM.

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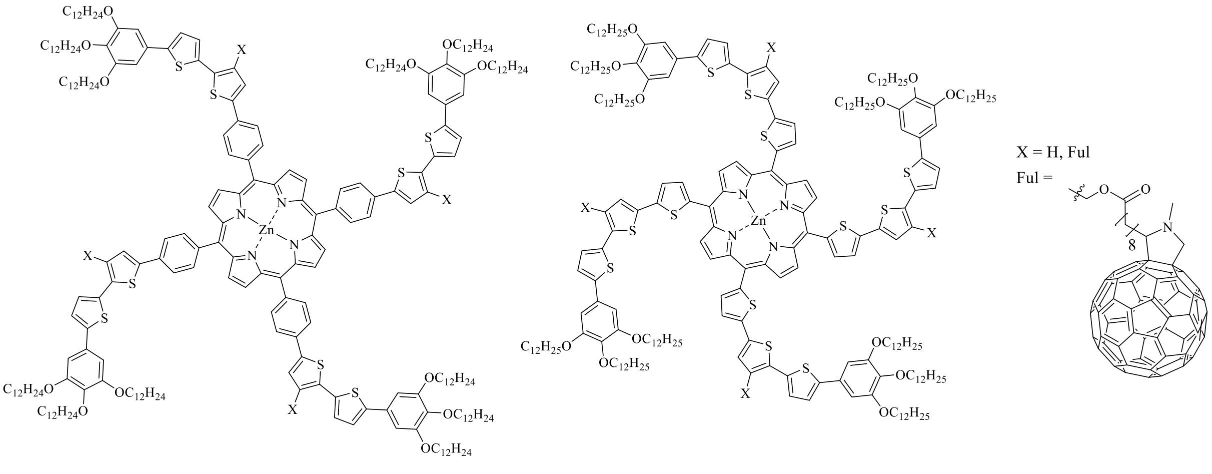
Supramolecular Click Mechanism and Fullerene-substituted Porphyrin Star Mesogens – a success story?

Lisa Reber, Matthias Lehmann*

University of Würzburg, Institute of Organic Chemistry, 97074 Würzburg, Germany

It has recently been shown that the supramolecular click mechanism works in 1 : 1 mixtures of zinc phthalocyanines star-mesogens with and without fullerene pseudo guests, producing well-ordered phthalocyanine columns with quadruple twisted fullerenes helices. The clearing temperatures were, however, extremely high [1]. Owing to the structural similarity porphyrines are of high interest since they lack the synthetically unavoidable production of stereoisomers found for the phthalocyanine derivatives and possess typically lower clearing temperatures [2, 3]. Therefore, unconventional porphyrin oligo(thienyl) discotic molecules were synthesized without and with fullerene attached to the conjugated arms to explore their potential for the click procedure and finally their performance as photovoltaic materials.

In this contribution, the challenging synthesis and molecular analysis of the unsubstituted **1**, **3** and fullerene-substituted zinc porphyrin oligo(thienyl) molecules **2**, **4** are highlighted. The thermotropic properties of the neat compounds and their 1 : 1 mixtures are explored by means of polarized optical microscopy, differential scanning calorimetry and comprehensive X-ray scattering.



1: X = H
2: X = Ful

3: X = H
4: X = Ful

Figure 1. Star-shaped, shape-persistent target molecules.

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* Author for Correspondence: matthias.lehmann@uni-wuerzburg.de

Tuning LCs Photoresists during Microfabrication

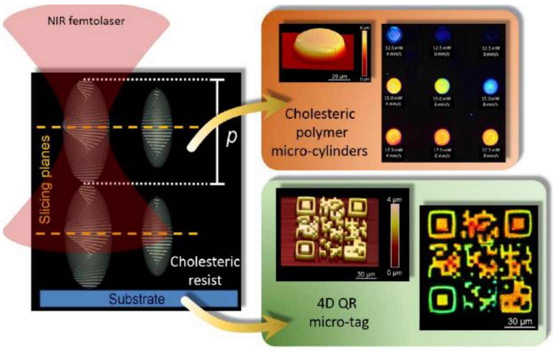
T. Ritacco[1,2], D.M. Aceti[3], A. Mazzulla[2], M. Giocondo[2], G. Cipparrone[1,2], and P. Pagliusi[1,2],*

[1] Physics Department, University of Calabria, Rende (CS) Italy
[2] CNR-Nanotec, Institute of Nanotechnology, S.S Cosenza, Rende (CS), Italy
[3] Institute of Electronics, Bulgarian Academy of Sciences, Sofia, Bulgaria

Two-photon crosslinking lithography (TPL) of liquid crystalline photoresists (i.e. reactive mesogens, RMs) has been proven to be highly versatile in the production of smart devices for use in various fields, such as optics, photonics, data storage, and security systems [1-3]. In particular, combining the versatility of TPL with the intrinsic properties of RMs shows great promise for the creation of physically unclonable functions (PUFs), which are highly effective in anti-counterfeiting measures [1].

TPL is a non-linear optical technique that exploits two-photon absorption process for the precise fabrication of complex structures at the nanoscale. When an ultrafast infrared laser is focused inside UV-sensitive RMs, it triggers crosslinking within a confined volume of nanometric sizes (i.e., voxel). Complex microstructures are fabricated by swiping the laser in 3D, which presents both the mechanical properties of the polymer and the optical response of the mesophase.

Here we focus on adding further “dimensions” to 3D microfabrication. Adopting a *graytone* TPL approach (i.e. locally tuning the exposure parameters), spatial partnering of the optical properties of nematic and cholesteric RMs is achieved in single-step microprinting session. In particular, we demonstrate an easy way to implement anisotropic-3D and color-3D printing, via local control of the optical axis, birefringence and helical pitch. With aim to create optical PUFs a 4D quick response (QR) code, made micron-sized square cuboid elements with different heights and selective structural color bands, is reported as a novel paradigm of secure authentication code.[4]



TPL in chiral RMs causes a reduction of the effective helical pitch as a function of the delivered energy dose. It translates in the possibility of tuning the selective color reflection. Security devices concealing a color code, with nanometric resolution, can be fabricated.

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* Author for correspondence: pasquale.pagliusi@fis.unical.it

3D printing of Liquid Crystal Elastomers for the development of artificial muscles

Ruggero Rossi[1*], Daniele Martella[1,2], Caterina Credi[1,3], Federico Carpi[4] and Camilla Parmeggiani[1,5]

[1]European Laboratory for Non-Linear Spectroscopy (LENS), Sesto Fiorentino 50019, FI, Italy
[2]Istituto Nazionale di Ricerca Metrologica (INRiM), Turin 10135, TO, Italy
[3]National Institute of Optics National Research Council (INO-CNR), Sesto Fiorentino 50019, FI, Italy
[4]Department of Industrial Engineering, University of Florence, Firenze 50139, FI, Italy
[5]University of Florence, Department of Chemistry, Sesto Fiorentino 50019, FI, Italy

Liquid Crystalline Elastomers (LCEs) are among the best candidates for artificial muscles development, thanks to their ability to produce mechanical work in response to an external stimulus (light, temperature, etc.). However, their use for biological application inside the human body, still remains a mayor challenge. Towards this objective, we developed a series of LCEs able to work as artificial muscles under illumination with visible light, [1] and we demonstrated their activation by mini-LED arrays [2] thus opening the way to prepare light responsive patches to support cardiac/muscular function *in vivo*. However, the obtainment of large samples and specific material shapes is limited by the preparation method used.

In this communication, we will describe the preparation and characterization of LCE-based artificial muscles prepared by a low-cost 3D printing machine. [3] Direct Ink Writing (DIW), an extrusion-based technique, has been used to shape the material and to control the liquid crystal alignment along the printing direction (Fig. 1a). A thiol-ene reaction of dyacrilate mesogens and dithiolic chain extenders was used to produce highly viscous oligomers that fit for the DIW; after the extrusion, the material has been crosslinked by UV curing.

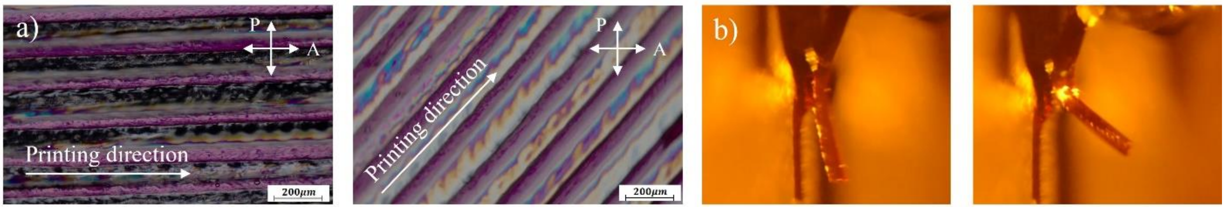

Figure 1. a) POM (Polarized Optical Microscopy) images of a 3D printed strip at different polarization angles; b) 3D printed strip actuation after light irradiation

Two LC-based inks showing different light actuation (under UV or visible light) have been prepared and characterized (Fig. 1b). The materials have been printed in different geometries and shapes allowing for a large-scale production of LCEs to develop custom-sized implantable patches.

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Phase Behaviour of Charged Gay-Berne/Lennard-Jones mixtures

Giacomo Saielli[1*], Valerio Mazzilli[1], and Katsuhiko Satoh[2*]

[1]ITM-CNR and Department of Chemical Sciences, University of Padova, Via Marzolo, 1 (PD), Italy
[2]Department of Chemistry, Osaka Sangyo University, Daito, Osaka, Japan

Ionic Liquid Crystals (ILCs) are materials entirely composed by ions, as ionic liquids (ILs), but exhibiting mesomorphism as in liquid crystals (LCs). In this presentation, we will highlight the results of molecular dynamics simulations of mixtures of charged spherical Lennard-Jones (LJ) particles and anisotropic Gay-Berne ellipsoids (GB) as models of colloidal suspension and molecular ILCs. The self-assembly behavior and mesomorphism have been studied for three types of GB systems: prolate (rod-like) ellipsoids of length-to-breadth ratio of 3 and 4.4, and oblate ellipsoids (disk-like) with thickness-to-width of 0.345. As can be seen in Figure 1, a very rich mesomorphism has been observed as a function of the temperature, charge and composition. The isotropic phase is stabilized by the charge which suppresses phase separation; an ionic nematic phase for rod-like systems is obtained in a wide range of temperatures and compositions [1,2], together with smectic phases. On the other hand, microphase segregation promotes the formation of unusual phases: the mixture with the longer GB ellipsoid [3] features phases with mono-dimensional triangular ionic channels filled with the anions (LJ particles), see Figure 1b). Discotic systems also show a very interesting behaviour. Besides the well-known discotic nematic and hexagonal columnar phases, depending on the charge and composition we have observed lamellar structure exhibiting an alternation of layers of disks and layers of spheres [4], see Figure 1c) for compositions rich in LJ, while a frustrated hexagonal columnar phase with an alternation of the tilt o the director is observed for systems rich in GB particles, see Figure 1d) [4]. The general behaviour is at variance with that one of the uncharged mixtures which undergo a macroscopic phase separation [2,5].

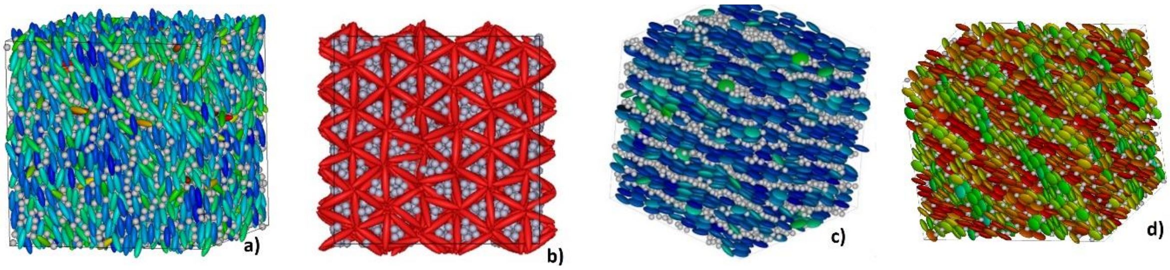

Figure 1. a) Ionic nematic phase formed by charged 1:1 GB(3):LJ. b) regular porous phase formed by charged 1:2 GB(4.4):LJ. c) lamellar phase formed by charged discotic 1:2 GB(0.345):LJ. d) frustrated hexagonal columnar phase formed by charged discotic 2:1 GB(0.345):LJ

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* Author for Correspondence: giacomo.saielli@unipd.it; ksatoh@las.osaka-sandai.ac.jp

Ramification and labyrinth instabilities in a ferroelectric nematic fluid exposed to electric fields

Marcell Tibor Máthé[1,2], Hiroya Nishikawa[3], Fumito Araoka[3], Ágnes Buka[1], Antal Jákli[1,4,5], Péter Salamon[1*]

[1]Institute for Solid State Physics and Optics, Wigner Research Centre for Physics, P.O. Box 49, Budapest H-1525, Hungary
[2]Eötvös Loránd University, P.O. Box 32, H-1518 Budapest, Hungary
[3]RIKEN Center for Emergent Matter Science, 2-1 Hirosawa, Wako, Saitama, 351-0198, Japan
[4]Materials Sciences Graduate Program and Advanced Materials and Liquid Crystal Institute, Kent State University, Kent, Ohio 44242, USA
[5]Department of Physics, Kent State University, Kent, Ohio 44242, USA

Ferroelectric nematic liquid crystals exhibit huge spontaneous electric polarization while keeping fluidity [1]. Such combination of properties may refer to an analogous behavior of ferroelectric nematics in electric fields compared to magnetic ferrofluids in magnetic fields. The free surface of ferrofluids becomes unstable in magnetic field and tends to show well known, spectacular spiky patterns named after Rosensweig [2]. However, there is an important difference between the electric and magnetic cases, namely that electric charges may play crucial role that have no counterpart in the magnetic case. The questions arise how the above-mentioned analogy is realized and are there any unexpected unique features of external field induced interfacial instabilities in ferroelectric nematics.

We present studies of sessile droplets and fluid bridges of a ferroelectric nematic liquid crystal in externally applied electric fields [3]. It was found that above a threshold, the undistorted basic state undergoes a fingering instability, which appears as a ramification process. Moreover, by applying higher voltages, a secondary instability resembling a labyrinth can be observed with a distinct critical voltage and morphology. To characterize the instabilities, the threshold voltages were determined as a function of frequency and temperature in various sample geometries. The results are interpreted in relation to the Rayleigh-type and Rosensweig-type instabilities observed in charged droplet and in ferrofluids, respectively. We point out the requirements for the instabilities by means of voltage and special sample properties.

Acknowledgement: This work was supported by NSF DMR 2210083 and by NKFIH FK142643.

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* Author for Correspondence: salamon.peter@wigner.hu

Exploiting flexoelectric coupling in RM734 and DIO: similarities and differences

Nerea Sebastián[1*], Matija Lovšin[1,2], Brecht Berteloot[3], Natan Osterman[1,2], Andrej Petelin[1,2], Richard J. Mandle[4,5], Satoshi Aya[6,7], Mingjun Huang[6,7], Irena Drevenšek-Olenik[1,2], Kristiaan Neyts[3] and Alenka Mertelj[1]

[1] Jožef Stefan Institute, Ljubljana, Slovenia
[2] University of Ljubljana, Faculty of Mathematics and Physics, (Ljubljana) Slovenia
[3] Liquid Crystals and Photonics Group, ELIS Department, Ghent University, (Ghent) Belgium
[4] School of Physics and Astronomy, University of Leeds, (Leeds) UK
[5] School of Chemistry, University of Leeds, (Leeds) UK
[6] School of Emergent Soft Matter, South China University of Technology, (Guangzhou) China
[7] Guangdong Provincial Key Laboratory of Functional and Intelligent Hybrid Materials and Devices, South China University of Technology, (Guangzhou) China

The polar coupling of ferroelectric nematic (N_F) materials with the confining media surfaces, results in a rich behavior of domain formation and 3D director structures, very different from that of classical non-polar nematic materials [1-3]. Control of alignment and domain formation is essential for their future applicability. Among the different techniques, photopatterning technology is especially promising for the achievement of tailored polarization structures [4]. Photopatterning allows for the accurate fabrication of aligning layers containing splay structures, which, through the flexoelectric coupling of the nematic director and polarization, result in controlled patterning of N_F ferroelectric domains.

In this contribution, we explore the different behavior of RM734 and DIO [5,6] in photopatterned cells, which evidences the difference in the flexoelectric properties of both materials. The different structures are investigated using polarizing optical microscopy, optical transmission simulations, second harmonic generation microscopy and interferometry. SHG investigations also expose the difference in the non-linear optical properties of both materials.

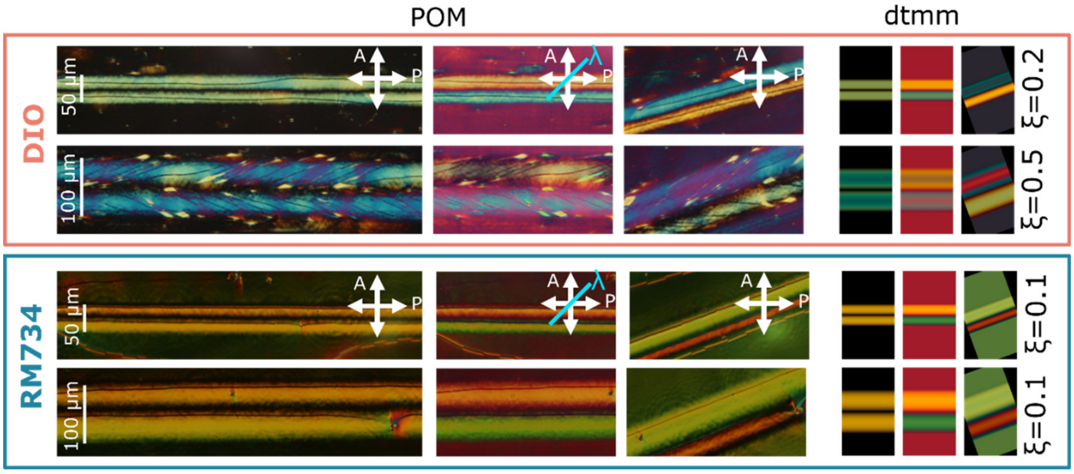

Figure 1. Comparison of POM and transmission spectra simulations for two different photopatterned splay lines in DIO and RM734, with maximum splay angle 45□ and periods of 50 and 100 µm.

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* Author for Correspondence: nerea.sebastian@ijs.si

Nematic Flow Induced by Active Surface Anchoring

Seyed Reza Seyednejad[1*] and Miha Ravnik[2]

[1] Faculty of Mathematics and Physics, University of Ljubljana, Ljubljana, Slovenia
[2] Jožef Stefan Institute, Ljubljana, Slovenia

Wet active matter can exhibit nematic order and its behaviour is underlied by the backflow effect that couples the orientational order and the material flow. To achieve a net flux, the distortions must be induced in a non-reciprocal manner. One of the most effective ways to induce the elastic distortions into the bulk of the NLC is to change the boundary conditions in time and space, which we call active surface anchoring. In this work, we show by using numerical simulations that if the surface anchoring non-reciprocally changes in time, e.g. like a wave, there will be a back-and-forth flow with a nonzero time average, as in a heartbeat. For example, in experiment, this could be achieved by grafting photosensitive elastomers onto the surface and reversibly changing their foldings by UV and visible light, leading to the surface anchoring switching. Specifically, we show that the magnitude of flow and the net flux and their dynamic variability, centrally depend on: (a) the dynamics of the surface anchoring in time and space, (b) geometry of the surfaces, and (c) system size.

* Author for Correspondence: seyed-reza.seyednejad@fmf.uni-lj.si

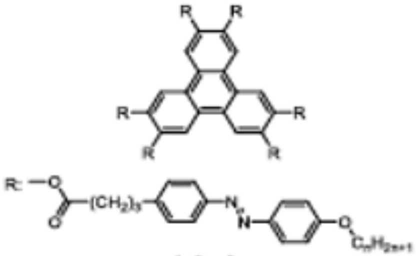
Dynamic change of molecular conformation generating a variation of liquid crystalline phases for triphenylene mesogens with peripheral alkoxyazobenzenes

Yo Shimizu[1*], Hikaru Sanada[2], Koji Kitagawa[2], Asumi Oka[2], Noboru Ohta[3], Tsuyoshi Kawai[1] and Kingo Uchida[2*]

[1] Graduate School of Science and Technology, Division of Materials Science, Nara Institute of Science and Technology (NAIST), Ikoma, Nara, Japan
[2] Department of Materials Chemistry, Faculty of Science and Technology, Ryukoku University, Otsu, Shiga, Japan
[3] Japan Synchrotron Radiation Research Institute (JASRI), Sayo, Hyogo, Japan

Rod and disc are the anisotropic shapes of two categories of mesogenic molecule. We found that a triphenylene with six tetradecyloxyazobenzenes at the periphenry connected by propylene ester groups (**1-C14-3**) exhibits calamitic – discotic bimesomorphy [1]. The similarity in phase transition behaviour was preliminarily reported for the alkyl homologues (C11-C16) of the ester-linked derivatives (**1-Cn-3)** [2].

In this study, mesomorphic phase transitions of the alkyl homologues (**1-Cn-3)** are compared to those of the corresponding ether-linked derivatives (**2-Cn-3**) and the Sm-Col phase transition mechanism is discussed.


1-Cn-3

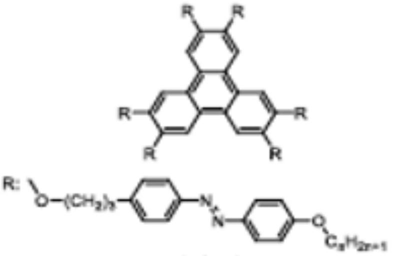

2-Cn-3

Fig. 1 shows the phase transition behaviour of the alkyl homologues of **1-Cn-3** obtained in the restudies with further purification of compounds. Only three homologues exhibit SmA phase, while Col phase is seen for all homologues. It was indicated that as SmA phase formation of **1-C10-3** [3], the SmA phase formed in those homologues has kinetically controlled character, meaning that rod-shape is easier to be formed than disc-shape, whilst theoretical simulations indicate that the disc-shaped conformer is more stable than rod-shape one. The X-ray diffraction studies for the aligned samples of SmA phase strongly indicate that the Sm-Col phase transition takes place with change of molecular conformation and it relates to the modification of π−π interactions among triphenylene units in a smectic layer which is variant on temperature change [4]. On the other hand, it was found that the alkyl homologues of **2-Cn-3** (n=12 and 14) show complicated mesophase sequences in comparison with **1-Cn-3**. The variation of mesophase on change of molecular conformation is discussed for rod-disc combined mesogenic systems.

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* Author for Correspondence: yo-shimizu@ms.naist.jp, uchida@rins.ryukoku.ac.jp

Thermal Conductivity of RM 734 Ferroelectric Nematic Material at the Ferroelectric-Ferroelastic Phase Transition

Dharmendra Pratap Singh[1], Michael Depriester[2], Benoit Duponchel[2] and Richard J. Mandle[3]

[1]Unité de Dynamique et Structure des Matériaux Moléculaires (UDSMM), Université du Littoral Côte d'Opale, 62228 Calais cedex, France
[2]Unité de Dynamique et Structure des Matériaux Moléculaires (UDSMM), Université du Littoral Côte d'Opale, Dunkerque, 59140, France
[3]School of Chemistry, University of Leeds, Leeds LS2 9JT, United Kingdom

The development of a new liquid crystal material with novel mesogenic features is of tremendous interest. A new liquid crystalline material viz. 4-[(4-nitrophenoxy)carbonyl]phenyl2,4-dimethoxybenzoate (RM734), exhibiting ferroelectric nematic phase (NF) has been recently reported [1-3]. Herein, we present the temperature-dependent thermal behaviour of the RM734 compound. The thermal conductivity (κ) was obtained from the formula: $\kappa = e.\alpha^{1/2}$, where e and α are the measured thermal effusivity and thermal diffusivity, respectively[4]. Both quantities were extracted via pyroelectric experiment in which the RM734 compound, placed in close contact with a pyroelectric sensor, is irradiated by a pulsed laser beam. The thermal diffusivity and effusivity were obtained under the back and front-detection configurations (Figure 1(a) and 1(b)). The thermal parameters are extracted from the pyroelectric signal at the ferroelectric-ferroelastic phase transition (Figure 1(c)).

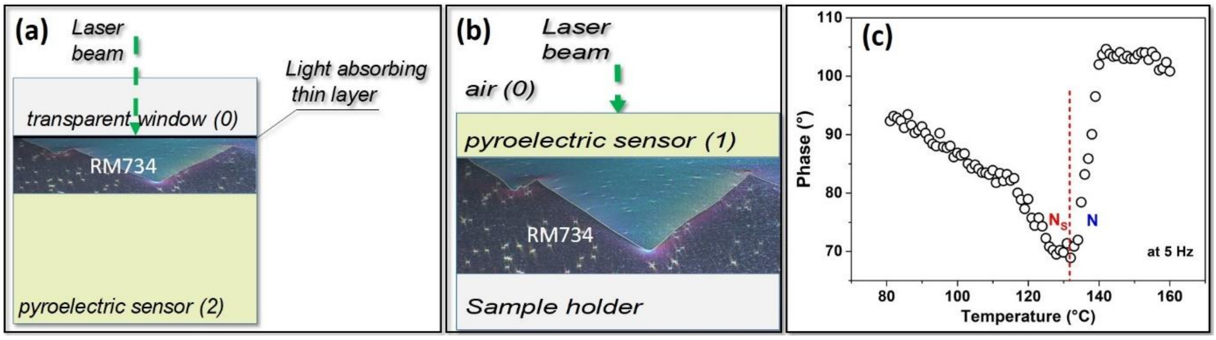

Figure 1. (a) Back detection configuration for the determination of the thermal diffusivity, (b) Front detection configuration for the determination of the thermal effusivity, and (c) Temperature dependence of the phase of the pyroelectric signal at 5 Hz frequency in back configuration.

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* Author for Correspondence: dharmendra.singh@univ-littoral.fr

Sustainable Formulations: Cellulose based Colloid-nematic Gels

Órlaith Skelton[1*] and Tiffany Wood[1]
[1]School of Physics and Astronomy, University of Edinburgh, Edinburgh, UK

Stiff, yet highly thinning, viscoelastic gels can be formed upon mixing colloids with homeotropic (normal) alignment into a nematic liquid crystalline medium. This is due to the entangled network of defect lines that percolate throughout the sample. Cellulose nematic phases can be created from biorenewable ingredients obtained from wood and seaweed.

In this work, the rheological properties of the colloid-nematic composite are explored. While the nematogen concentration has little to no effect on the composite, we show that rheological properties are greatly impacted by colloid volume fraction. We also show broad linear viscoelastic regions, suggesting high stability of the composite gels.

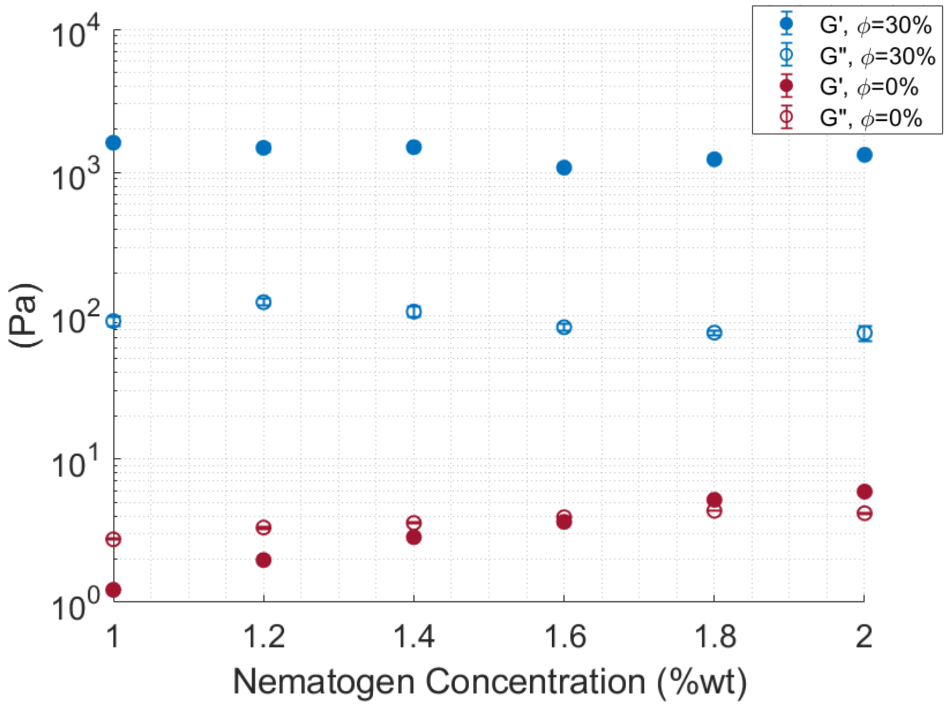

Figure 1: Effects on linear viscoelastic region of composite with colloid volume fractions ϕ=0 and ϕ=30% against increasing CNC concentration.

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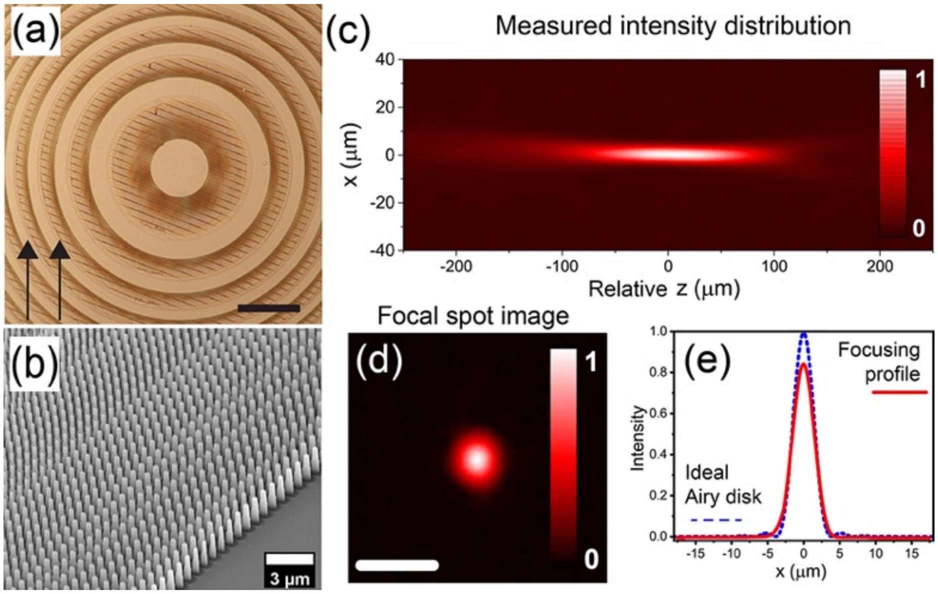
* Author for Correspondence: O.Skelton@sms.ed.ac.uk

All-Optical Tunability of Metalenses Permeated with Liquid Crystals

G. Palermo[1], A. Lininger[2], A. Guglielmelli[1], L. Ricciardi[1], G. Nicoletta[1], A. De Luca[1], J-S Park[3], S W D. Lim[3], M. L. Meretska[3], Federico Capasso[3], and Giuseppe Strangi[1,2]

[1]Department of Physics, NLHT-Lab, University of Calabria and CNR-NANOTEC, 87036 Rende, Italy;
[2]Department of Physics, Case Western Reserve University, Cleveland, Ohio 44106, United States;
[3]Harvard John A. Paulson School of Engineering and Applied Sciences, Harvard University, Cambridge, Massachusetts 02138, United States.

ABSTRACT: Metasurfaces have been extensively engineered to produce a wide range of optical phenomena, allowing exceptional control over the propagation of light. However, they are generally designed as single-purpose devices without a modifiable postfabrication optical response, which can be a limitation to real-world applications. In this work, we report a nanostructured planar-fused silica metalens permeated with a nematic liquid crystal (NLC) and gold nanoparticle solution. The physical properties of embedded NLCs can be manipulated with the application of external stimuli, enabling reconfigurable optical metasurfaces. We report the all-optical, dynamic control of the metalens optical response resulting from thermoplasmonic-induced changes of the NLC solution associated with the nematic−isotropic phase transition. A continuous and reversible tuning of the metalens focal length is experimentally demonstrated, with a variation of 80 μm (0.16% of the 5 cm nominal focal length) along the optical axis. This is achieved without direct mechanical or electrical manipulation of the device. The reconfigurable properties are compared with corroborating numerical simulations of the focal length shift and exhibit close correspondence.



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Order and disorder induced by smectic liquid crystal topological defects on gold nanoparticles networks

Caterina Tosarelli[1*], H. Jeridi[1,2], J.D. Niyonzima[1,3], L. Essaoui[1], A. Vlad[4], A. Coati[4], D. Constantin[5], Y. Garreau[4,6], D. Babonneau[7], B. Croset[1], I. Trimaille[1], C. Abadie[1] , S. Royer[8], M. Goldmann[1,4], E. Lhuillier[1], M. Treguer-Delapierre[10] and E. Lacaze[1]

1. Institut des NanoSciences de Paris, CNRS, Sorbonne Université, 75005 Paris, France
Laboratory Name, Department Name, Line research organization or University 1, Line research organization or University 2, etc., City, Country
2. OMNES Education Research Center, ECE Paris, 37 Quai de Grenelle, 75015 Paris, France
3. Physics department, School of Science, College of Science and Technology, University of Rwanda, Po. Box: 3900, Kigali, Rwanda
4. Synchrotron SOLEIL, BP 48, L'Orme des Merisiers, 91192 Gif sur Yvette Cedex, France
5. Universite´ de Strasbourg, Institut Charles Sadron, CNRS UPR022, 67034 Strasbourg Cedex, France
6. Universite´ Paris Cite´, Laboratoire Mate´riaux et Phe´nome`nes Quantiques, CNRS, F-75013 Paris, France
7. Departement Physique et Mecanique des Materiaux, Institut P', UPR 3346 CNRS, Universite´ de Poitiers SP2MI, TSA 41123, 86073 Poitiers cedex 9, France
8. CNRS, Sorbonne Université, Laboratoire de la Molecule aux Nano-objets; Reactivité, Interactions et Spectroscopies MONARIS, 4 Pl Jussieu, Case Co, F-75005 Paris, France
9. European Synchrotron Radiation Facility (ESRF), Grenoble, France
10. ICMCB, CNRS, Université de Bordeaux, 33608 Pessac, France

When it comes to composites of liquid crystals (LC) and nanoparticles, topological defects become extremely interesting. Depositing 8CB on a rubbed PVA surface we observe a pattern of flattened hemicylinders (the so called "oily streaks") presenting different kinds of topological defects. Line defects together with a 2D melted grain boundary oriented along the direction of stripes appear in order to accommodate the rotating smectic layers with small thickness (Figure 1). Previous results from our group show that these defects are able to trap nanoparticles and to transmit them their geometrical shape, allowing the coexistence of different kinds of oriented nanoparticles assemblies [1]. It has been demonstrated that the 1D defects can organize nanoparticles into chains and that the melted grain boundary creates a ribbon where nanospheres are arranged in an hexagonal network. When using gold nanoparticles, the networks can activate interesting collective properties like the Localized Surface Plasmon Resonance (LSPR), whose wavelength will be controlled by the shape of the network and by the distance between the nanoparticles.

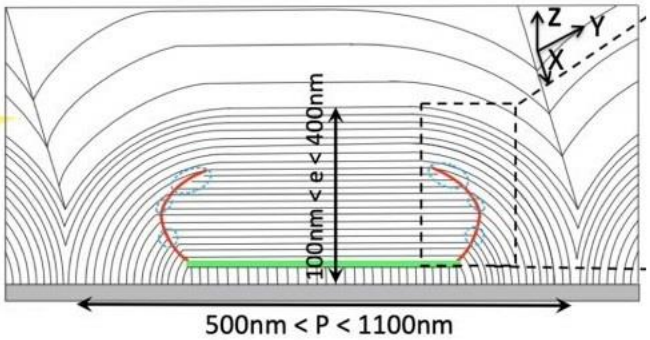
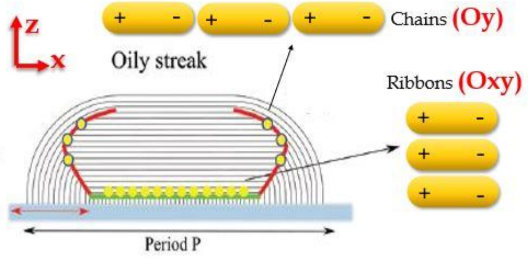


Figure 1. Section of hemicylinder pattern. The red lines indicates the dislocations along which six 1D defects appear, the green line indicates the melted grain boundary forming a 2D defect.

We are currently interested in using gold nanorods functionalized with thiol-ended polystyrene to confine and organize them in the defects and study their LSPR properties. Absorption measurements reveal that these rods can form chains in which they organize in a tip-to-tip configuration at small concentration, coexisting with ribbons at large concentration. In the ribbons, they are arranged in a side-to-side configuration where nanorods are perpendicular to the chains (Figure 2). This latter orientation is perpendicular to the one obtained with nanorods functionalized with alkyl chains [2]. This suggests that the ligands play a fundamental role in the interaction between the nanoparticles and the liquid crystal: they couple with the smectic layers just below the 2D defect, controlling the orientation and organization of the nanorods. These results demonstrate that playing with ligands' nature will lead us to control the organization of the nanoparticles and therefore the light absorption from the composite. We also aim at exploiting the temperature-dependent order of the LC to control the orientation of the nanorods, activating their interaction with light and its absorption.



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Active nematic-induced dynamics of passive polymers

Zahra Valei[1], Tyler N. Shendruk*[1]

[1]School of Physics and Astronomy, University of Edinburgh, Edinburgh, EH9 3FD, United Kingdom

Anisotropic and rheologically complex materials are ubiquitous in living systems, in which biochemically fuelled activity can give rise to intriguing nonequilibrium effects that act on small solutes, whole organelles, and extended biomolecular polymers. Of these, passive polymers embedded in active liquid crystalline solvents are particularly interesting because of the interplay between the broken symmetry of the anisotropic medium, nonequilibrium activity and the conformational degrees of freedom of the macromolecules. While previous studies have either focused on active polymers embedded in passive fluids [1] or passive polymers in nonequilibrium thermal baths [2], this talk will report the first study of a passive polymer in active nematic flows. We numerically study the structural and dynamical features of individual, semiflexible polymers in active nematic liquid crystals, employing a hybrid Multi-Particle Collision Dynamics [3] and Molecular Dynamics [4] simulation. The intimate coupling of thermal noise, hydrodynamic interactions, orientational ordering, polymer entropy and activity leads to complex dynamics. We begin our study in the zero-activity limit by qualifying polymer conformations through shape descriptors, including the radius of gyration and asphericity, as a function of nematic coupling. We show how these conformational states contribute to anisotropic diffusion through decreased mobility perpendicular to the nematic orientation. We find that the macromolecular properties are governed by hairpins, sudden kinks along the backbone of the polymer, which themselves exhibit one dimensional diffusion-annihilation dynamics. We then demonstrate how activity profoundly alters these results through hairpin creation and annihilation. For this purpose, we simulate worm-like Kratky-Porod polymers embedded in 2D extensile active nematics. Our focus is on the interaction between singularities — hairpins along the backbone of the polymer and disclinations in nematic orientation. (Figure 1). We find that self-motile +1/2 disclinations frequently collide with the polymer, often deforming the polymer and causing it to aperiodically cycle through folded and expanded conformations, which are correlated with effective polymer motility. These dynamics are strikingly different from those observed in previous simulations of externally activated flexible polymers suspended in out-of-equilibrium heat baths [5]. This highlights the significance of the nature of activity in the actuation of the polymers, and suggests pathways for designing active/adaptive, biomimetic, liquid crystalline materials.

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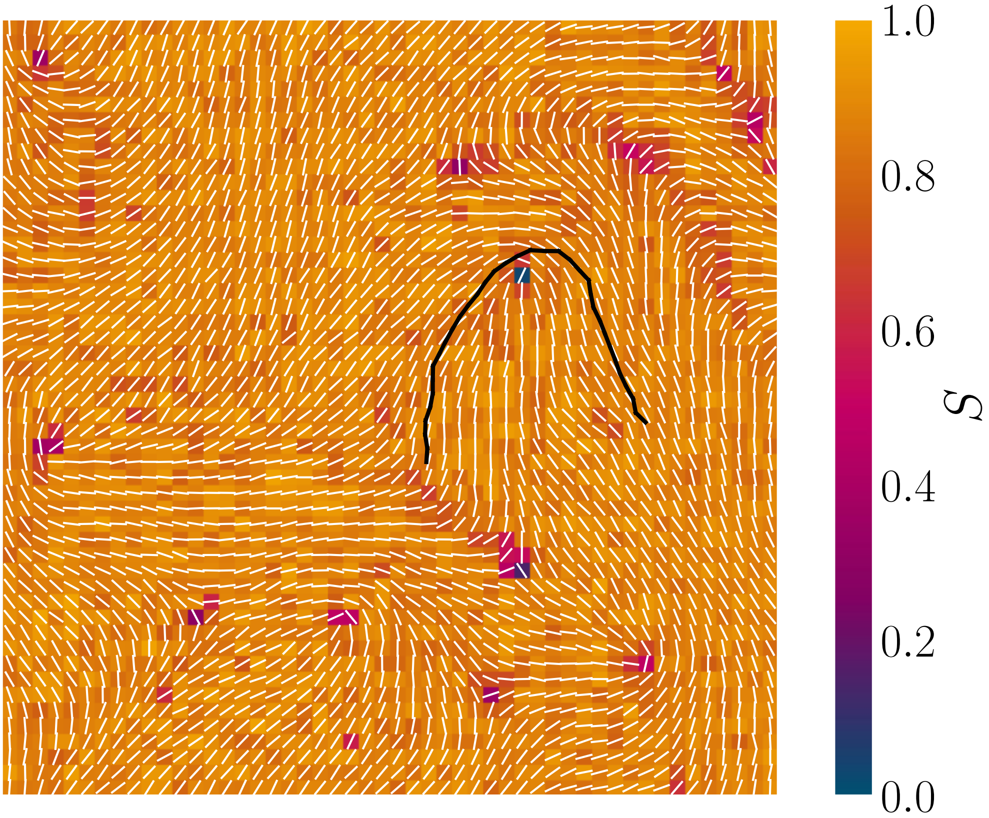

Figure 1: An example snapshot showing a typical interaction between a broad hairpin along the polymer backbone and a self-motile +1/2 disclination. The +1/2 defect actively drives the polymer, pushing it in the direction of the bent hairpin and endowing it with propulsive dynamics on short timescales. The black line represents the worm-like polymer composed of N = 35 monomers, white lines denote the nematic director field, and the color shows the scalar order parameter S.

Lyotropic nematic liquid crystals: interplay between micellar shape and elasticity

Stella Varytimiadou[1*], Per Rudquist[2], Clarissa F. Dietrich[1], and Frank Giesselmann[1]

[1]Institute of Physical Chemistry, University of Stuttgart, Stuttgart 70569, Germany
[2] Microtechnology and Nanoscience, Chalmers University of Technology, Gothenburg 41296, Sweden

In the classic work by Oseen and Frank [1 , 2], the elastic behavior of a nematic (N) liquid crystal is described by the three bulk elastic constants for splay (K_1), twist (K_2) and bend (K_3) deformations of the director field. For common thermotropic liquid crystals, the three elastic constants are of the same order of magnitude and the one-constant approximation ($K_1 \approx K_2 \approx K_3$) is often applied in theory and experiment. In case of lyotropic chromonic liquid crystals, however, exceptions from the one constant approximation have been reported, with K_2 being at least one order of magnitude smaller than K_1 and K_3 [3 , 4].

Surprisingly, very little is known about the elasticity of lyotropic nematic systems that are formed by micellar building blocks, despite the fact that they are by far the most ubiquitous class of lyotropic liquid crystals. These surfactant-based systems have been known for a long time and are of outmost importance, since they are found not only in biological structures (e.g. cell membranes) but also in our daily lives (e.g. washing agents).

Recently, we have reported first studies on the elastic behavior of a nematic liquid crystal formed by disk-shaped micelles, revealing the same unusually small twist elastic constant [5]. In this contribution we aim to elucidate the impact of the micellar shape on the elasticity of the lyotropic nematics and will present values of the elastic constants for two further micellar systems. The first is a standard nematic phase of rod-like micelles, while the second system contains two oppositely charged surfactants, forming very long worm-like micelles, the length of which is in the micron range (Fig. 1a). Following the dynamic light scattering procedure in [3], two overdamped relaxation processes are observed (Fig. 1b), indicating a significant difference between the splay and twist elastic constants. Analyzing the data, we find that in both micellar N_C phases, K_2 is one order of magnitude smaller than K_1 and K_3.

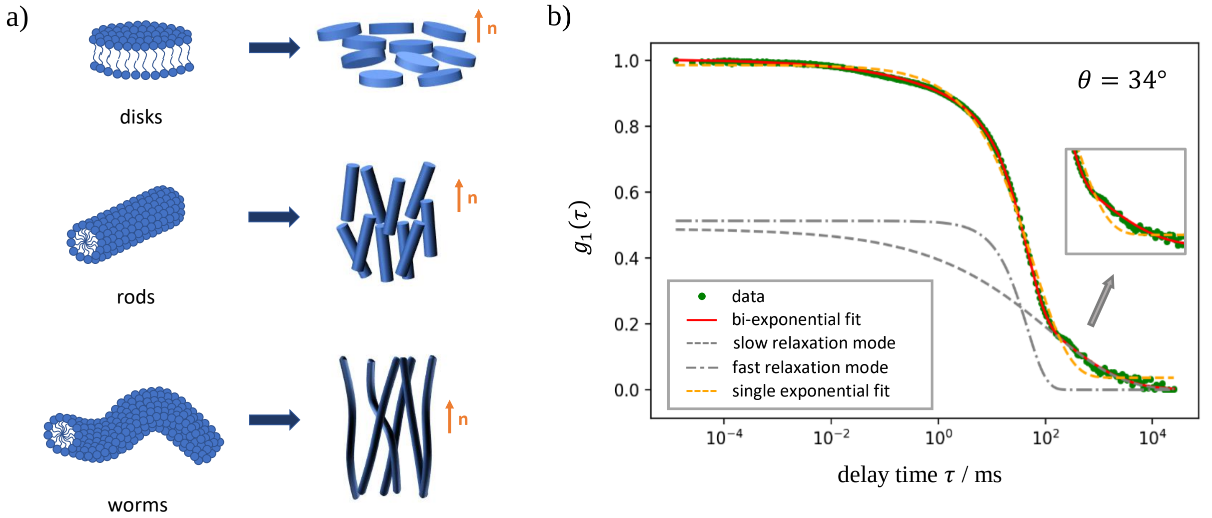

Figure 1. Elasticity in lyotropic nematic liquid crystals: a) shape of the micellar building blocks of the systems studied so far. b) Dynamic light scattering analysis for a lyotropic nematic phase of rod-like micelles. Amplitude pseudo-cross-correlation function g_1 plotted against the delay time τ at a scattering angle $\theta = 34°$.

These results indicate that an extremely small twist elastic constant is indeed an inherent property of all lyotropic nematic systems, even though their chemical compositions as well as the shapes and dimensions of their supramolecular building blocks are very different. The reasons behind this unique phenomenon will be discussed qualitatively considering the flexible nature of the molecular assemblies in lyotropic phases.

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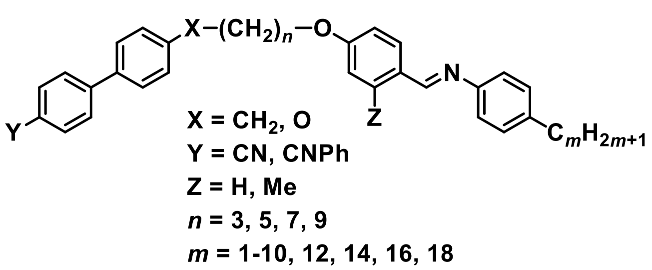
* Author for Correspondence: stella.varytimiadou@ipc.uni-stuttgart.de

New investigations into the twist-bend smectic phases (SmC$_{TB}$)

Rebecca Walker[a*], Ahlam Alshammari[a], Abigail Pearson[a], Ewan Cruickshank[a], Magdalena Majewska[b], Damian Pociecha[b], Ewa Gorecka[b], John M. D. Storey[a] and Corrie T. Imrie[a]

[a] Department of Chemistry, University of Aberdeen, Aberdeen, UK
[b] Department of Chemistry, University of Warsaw, Warsaw, Poland

Over a decade since they were first theorized,[1] heliconical liquid crystal phases formed by achiral, bent-shaped molecules are one of the newest classes of liquid crystal phases and have recently attracted considerable global research interest. The twist-bend nematic phase, N$_{TB}$, is an intriguing and unique example of spontaneous mirror symmetry breaking in a fluidic state; a locally chiral phase formed from achiral molecules. In the N$_{TB}$ phase, the director forms a helix and is tilted with respect to the helical axis; the spontaneous formation of chirality ensures that equal numbers of left- and right-handed degenerate helices are formed.[2] More recently, heliconical twist-bend smectic C (SmC$_{TB}$) phases have also been discovered for liquid crystal dimers[4] and in bent-core mesogens,[5] and it appears that a range of variants of this phase, similar to the SmC* subphases observed for chiral molecules, are possible (see *Figure 1*).



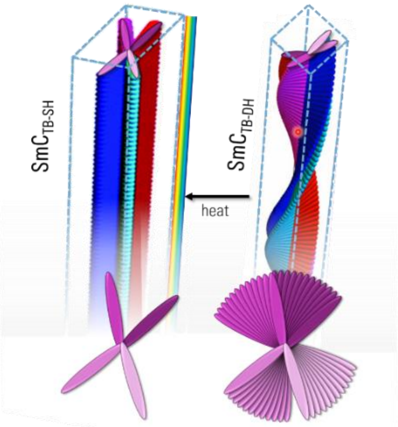


Figure 1. General dimeric structure of twist-bend smectic-forming liquid crystals (above) and sketches of two variants of the twist-bend smectic C phases, the "single helix" (SmC$_{TB-SH}$) and "double helix" (SmC$_{TB-DH}$).

Here we report the synthesis and extensive characterisation of several new homologous series of liquid crystals based on a dimeric structure, shown also in *Figure 1*, which show rich liquid crystal polymorphism including twist-bend nematic and smectic phases. Despite the molecules themselves being achiral, fascinating phenomena observed for these series include: the twist-bend arrangement in monolayer, bilayer and intercalated structures, transitions between novel twist-bend smectic phases with differing helical structures, structural chirality at different length-scales, and – for the first time in achiral molecules – the exhibition of a photonic bandgap for visible light.

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*Author for Correspondence: rebecca.walker@abdn.ac.uk

The structure of the ferroelectric nematic phase: insights from molecular dynamics simulations

Mark R. Wilson[1*] and Toby R. C. Thompson[1]

[1] Department of Chemistry, University of Durham, Durham DH1 3LE, UK

The reported experimental discovery of a ferroelectric nematic (N_F) phase is an exciting new development in liquid crystal research. [1-3] The phase's origins are poorly understood, leading to derivatives of the first two mesogens to be discovered making up most of the known N_F mesogens.[1] At a molecular level, the phase is unusual, as often molecules with large dipole moments preferentially align with anti-parallel dipole ordering, as seen (for example) in cyanobiphenyl-based nematics, such as 5CB. However, in the N_F phase, large molecular dipoles preferentially align in a parallel direction. The new phase has several potential applications in displays and novel technology due to its unprecedented polarization.

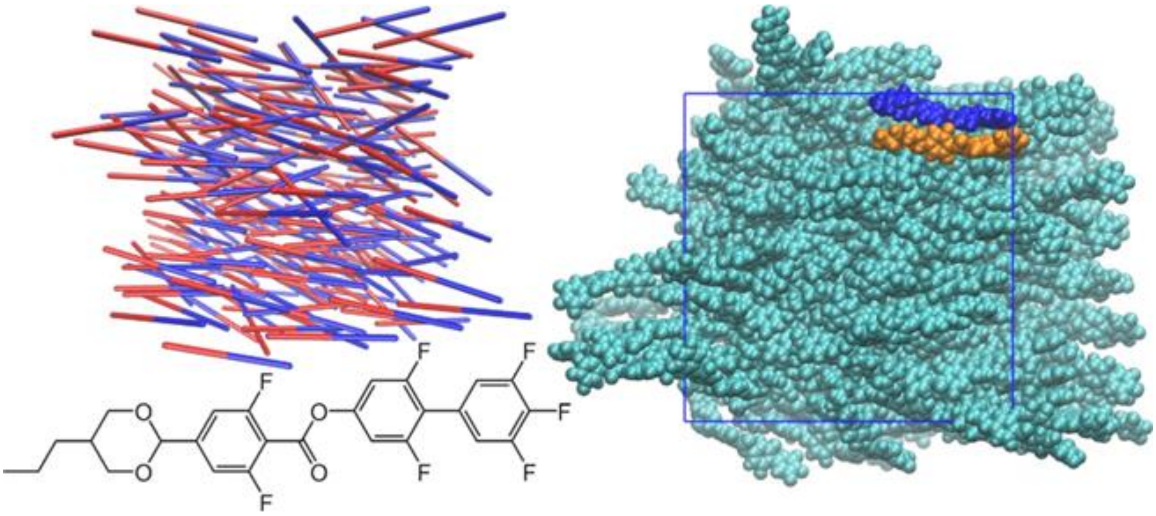

Figure 1: Visualisation of a ferroelectric nematic phase of "DIO-F ".

Here we report state-of-the-art atomistic molecular dynamics simulations of an N_F mesogen: "DIO-F" (Fig. 1). We initially use quantum chemical calculations to optimise a new force field for DIO-F, and from molecular dynamics simulations of up to 648 molecules, we obtain excellent predictions of phase properties and transition temperatures. The N_F phase is obtained by cooling an isotropic phase and allowing the N_F phase to grow slowly over hundreds of nanoseconds of simulation. Cylindrical distribution functions are calculated to investigate the role of specific preferred intermolecular pairings. The calculations allow different explanations for the stability of the N_F phase to be probed.

N_F stability is found to be promoted by a combination of local quadrupolar interactions and microphase separation of hydrophobic parts of the molecule. These interactions are sufficient to overcome the tendency for anti-parallel dipole alignment that is seen in many low molecular weight nematic and smectic systems.

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* Author for Correspondence: mark.wilson@durham.ac.uk

Particle-resolved topology of colloidal smectics

René Wittmann[1*], Paul A. Monderkamp[1], Michael te Vrugt[2], Louis B.G. Cortes[3], Jingmin Xia[4], Iago Grobas[5], Raphael Wittkowski[2], Patrick E. Farrell[6], Dirk G.A.L. Aarts[5] and Hartmut Löwen[1]

[1]Theoretical Physics II: Soft Matter, Heinrich-Heine-Universität Düsseldorf, Germany
[2]Institut für Theoretische Physik, Westfälische Wilhelms-Universität Münster, Germany
[3]College of Meteorology and Oceanography, National University of Defense Technology, China
[4]School of Applied and Engineering Physics, Cornell University, Ithaca, NY, USA
[5]Physical and Theoretical Chemistry Laboratory, University of Oxford, United Kingdom
[6]Mathematical Institute, University of Oxford, United Kingdom

We present a general classification scheme [1] of the topological structure of smectic colloidal liquid crystals in two-dimensional confinements, dictated by the interplay between the intrinsic layering and the externally imposed boundary shape. Thereby, we demonstrate that topological defects emerge in the form of spatially extended grain-boundaries, whose orientational order is characterized by coexisting nematic and tetratic symmetry. We examine these intriguing topological properties by means of real-space microscopy experiments of colloidal rods, Monte-Carlo simulations, fundamental-measure-based density functional theory (DFT), and a phenomenological Q-tensor model [2]. The structural details agree on a quantitative level, as shown in Figure 1.

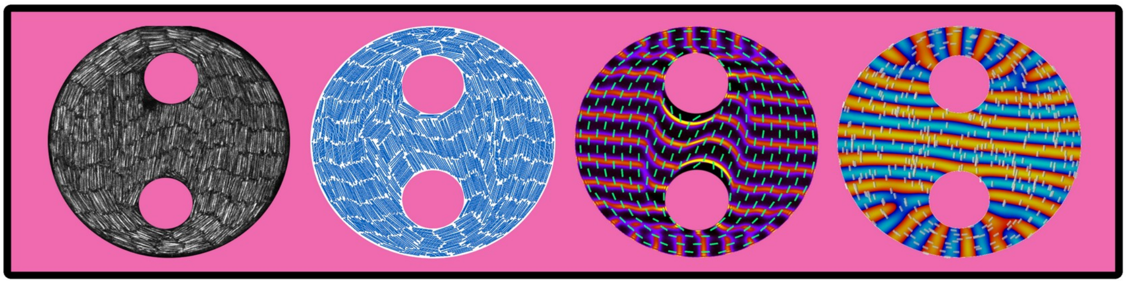

Figure 1. Example structures in a two-holed disk obtained with colloidal experiments, Monte-Carlo simulations, density functional theory and Q-tensor theory [2].

We analyze the typical shape of grain-boundary networks in a large range of polygonal confinements [1] and determine the stability of different competing topological states in nontrivial domains with additional interior boundaries [2, 3]. We also extend the concept of coexisting nematic and tetratic order to three spatial dimensions [4] and discuss the relation between orientational topology and network topology of smectic layers [5]. Finally, we show how to use network topological charges to characterize interlocked layer structures of L-shaped particles in two dimensions [5].

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* Author for Correspondence: rene.wittmann@hhu.de

Comparison between three ferronematic compounds with different phase sequence

Neelam Yadav[1*], Yuri P. Panarin[1,2], Wanhe Jiang[3], Jagdish K. Vij[1] and Georg Mehl[3]

[1]Dept. of Electronic and Electrical Engineering, Trinity College, The University of Dublin, Ireland
[2]Department of Electrical and Electronic Engineering, TU Dublin, Dublin, Ireland
[3]Department of Chemistry, University of Hull, UK

Three different ferronematic compounds, well-known RM734, DIO and a new WJ-16C were studied using a range of complimentary techniques. All these compounds exhibit extremely large dipole moments of order of ~10 D and recently discovered ferronematic phase, while the phase sequences are different and shown below:

- RM734: Iso 187.9°C N (N_F 132.7°C) 139.8°C Cr
- DIO: Iso 173.8°C N 83.5°C N_X 66.8°C N_F
- WJ-16C: Iso 176°C N_F 114.3°C SmA_F 80°C Cr

In addition to N_F phase, RM734 shows one paranematic phase with one collective relaxation process [1] in the frequency range of 1 Hz to 10 MHz while the compound DIO shows two phases and additional relaxation process (Fig.1a, red symbols), which originates from the polar/chiral domains arising from the spontaneous symmetry breaking of an achiral system in the nematic phase [2,3]. The appearance of chiral domains in the high temperature nematic phase of DIO is explained by the spontaneous symmetry breaking occurring due to the saddle-splay elasticity and is followed by separation of the stable helical conformers of the opposite chirality. Both RM734 and WJ-16C do not show any presence of chiral domains in the nematic phases. The novel compound WJ-16C in addition to the ferroelectric nematic phase exhibits the smectic phase, presumably SmA_F, observed in derivatives of DIO [4]. Preliminary dielectric study of this compound reveals only one collective relaxation process with very intriguing temperature dependence and jump at N_F-SmA_F transition (Fig.1b). More details on this compound will be presented in the accompanied paper.

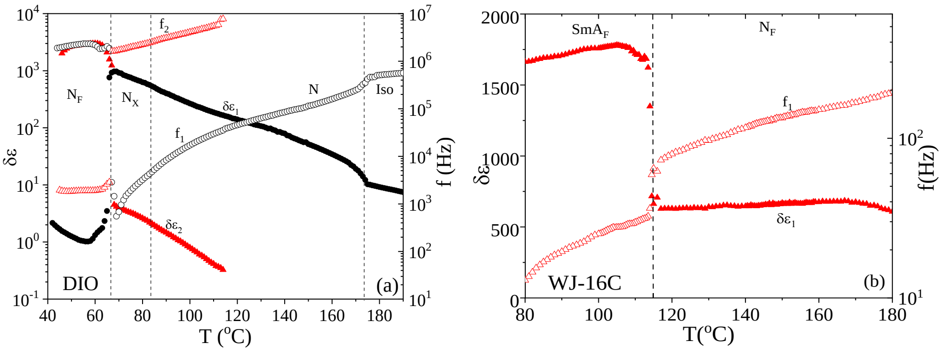

Figure 1. Dielectric spectra of (a) DIO and (b) WJ-16C.

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* Author for Correspondence: yadavn@tcd.ie

Gold nanorods-based biosensor with photo-responsive liquid crystals enables the detection of harmful pathogens in potable water

Federica Zaccagnini[1,*], Daniela De Biase[1], Seok-In Lim[2], Kwang-Un Jeong[2], Selenia Miglietta[3], Viviana Scognamiglio[4], Nicholas Godman[5], Dean R. Evans[5], Michael McConney[5], Francesca Petronella[4] and Luciano De Sio[1,6]

[1]Department of Medico-Surgical Sciences and Biotechnologies Sapienza University of Rome, Latina, Italy,
[2]Department of Polymer Nano Science and Technology, Department of Nano Convergence Engineering, Jeonbuk National University, Jeonju, Republic of Korea,
[3]Department of Anatomy, Histology, Forensic Medicine and Orthopaedics, Sapienza University of Rome, Italy,
[4] National Research Council of Italy, Institute of Crystallography, CNR-IC, Rome Division, Area della Ricerca Roma 1 Strada Provinciale 35d, n. 9 - 00010 Montelibretti (RM),
[5]US Air Force Research Laboratory, Wright Patterson Air Force Base, Ohio, USA,
[6]Center for Biophotonics Research, Department of Medico-Surgical Sciences and Biotechnologies, Sapienza University of Rome, Latina, Italy

NANO-LC is an international and multidisciplinary project aiming to realize a nanotechnology-inspired biosensor that can selectively recognize low concentrations of hazardous pathogens intentionally or unintentionally dispersed in drinkable water. To this end, a gold nanorods (AuNRs) array is immobilized on a rigid and optical transparent substrate through the layer-by-layer deposition method. The biosensor exploits the Localized Surface Plasmon Resonance (LSPR) phenomenon of highly monodispersed AuNRs and achieves high sensitivity to the changes in the surrounding medium, producing a visible colour change. The biofunctionalization with a specific antibody enables the selective recognition of pathogens in the water flow passing through the microfluidic channels, suitably fabricated and permanently bonded on the plasmonic surface. Light-sensitive liquid crystals (LCs) constitute the second active layer of the biosensor: it enables an independent double check and quantitative measurement of the bacteria concentration exploiting the light sensitivity of azo-benzene-based LC molecules. Indeed, the phase retardation behaviour of a well-aligned and light-responsive LC film represents an innovative technology for monitoring bacteria concentration. The photothermal properties of highly dense and well-monodispersed AuNRs provide high photothermal efficiency conferring light disinfection properties to the plasmonic platforms. Under multicolors or white light irradiation, the localized temperature increasing (65-70 °C) inactivates the bacteria cells, and once they are properly removed, the biosensor can be efficiently reutilized. Moreover, ongoing efforts are devoted to implementing a new generation of LCs soluble in water that can ultimately lead to the green transition of the proposed technology. [1]

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* Author for Correspondence: f.zaccagnini@uniroma1.it

Strength from defects: Topological barriers to defect nucleation generate large mechanical forces in a cholesteric

Bruno Zappone[1*] and Roberto Bartolino[2]

[1] Consiglio Nazionale delle Ricerche – Istituto di Nanotecnologia (CNR-Nanotec), 87036 - Rende, Italy
[2] Università della Calabria – Dipartimento di Fisica, 87036 - Rende, Italy

Common fluids cannot sustain static mechanical stresses at the macroscopic scale because they lack molecular order. Conversely, crystalline solids exhibit long-range order and mechanical strength at the macroscopic scale. Combining the properties of fluids and solids, liquid crystal films respond to mechanical confinement by both flowing and generating static forces. The elastic response, however, is very weak for film thicknesses exceeding 10 nm. In this study, the mechanical strength of a fluid film was enhanced by introducing topological defects in a cholesteric liquid crystal, producing unique viscoelastic and optomechanical properties. Using a surface forces apparatus (SFA), the cholesteric was confined under strong planar anchoring conditions between two curved surfaces with sphere-sphere contact geometry, similar to that of colloidal particles, creating concentric dislocation loops. During surface retraction, the loops shrank and periodically disappeared at the surface contact point, where the cholesteric helix underwent discontinuous twist transitions, producing weak oscillatory surface forces. On the other hand, new loop nucleation was frustrated by a topological barrier during fluid compression, creating a metastable state. This generated exceptionally large forces with a range exceeding 100 nm, as well as extended blue-shifts of the photonic band-gap. The metastable cholesteric helix eventually collapsed under a high compressive load, triggering a stick-slip-like cascade of defect nucleation and twist reconstruction events. These findings were explained using a simple theoretical model and suggest a general approach to enhance the mechanical strength of 1d-periodic materials, particularly cholesteric-colloid mixtures.

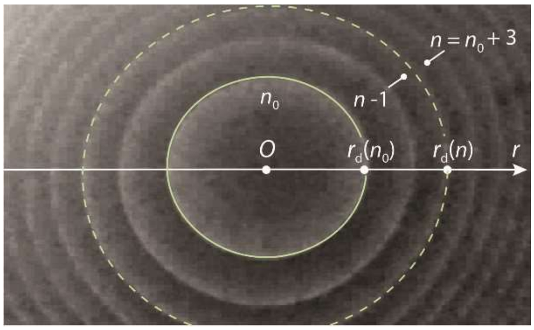

Figure 1. Optical micrograph of an array of concentric dislocation loops. The solid circle indicates the innermost loop with radius $r_d(n_0)$ encircling a defect-free region around the sphere-plane contact point, where the CLC helix makes n_0 half turns. The dashed circle line indicates an outer loop with radius $r_d(n)$ separating two regions with $n = n_0 + 3$ and $n - 1$ half-turns. r is the lateral distance from the contact point ($r = 0$) along the axis of the bottom cylinder.

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* Author for Correspondence: bruno.zappone@cnr.it

Order parameter modelling using molecular simulation techniques

G. Zhao[1*], T. Le[1], M. R. Wilson[2] and A. J. Masters[1]

[1] Department of Chemical Engineering, University of Manchester, Manchester M13 9PL, UK
[2]Department of Chemistry, University of Durham, Durham DH13LE, UK

Order parameter modelling is used to model a nematic liquid crystal at the mesoscale. Typically such models make use of an underlying Helmholtz energy functional, expressed in terms of the Q-tensor. To obtain the equilibrium state of the nematic, the Helmholtz energy is minimised with respect to Q. Generally, the minimisation is carried out numerically over a set of grid points. Order-parameter modelling methodology has been used to study a wide variety of liquid crystal devices, the properties of colloidal particles suspended in a nematic host and much more besides.[1]

To model more complex liquid crystals, such as biaxial smectic or banana phases, one has to deal with an increased number of degrees of freedom and numerical minimisation of a Helmholtz energy functional on a grid becomes more problematic. For such systems, a particle-based or Lagrangian formulation has its attractions, where an average over particle positions and orientations can yield the required information.

Here we propose the application of many body dissipative particle dynamics (MBDPD) techniques[2] to liquid crystals. The underlying Helmholtz energy functional is converted into a potential energy function. Standard molecular Monte Carlo and molecular dynamics techniques are used to track particle motion, whereupon an ensemble or time average yields the required properties. No sophisticated numerical minimisation techniques are needed, so one may study functionals with many degrees of freedom, such as have been proposed for the phases of bent core particles.[3] Here we provide a proof of principle of this technique by applying it to the nematic phase. We show that we can successfully model nematic behaviour, including the effects of an external field, anchoring and elastic deformations. We do not believe that our suggested methodology will be competitive with existing techniques for nematic phase modelling, but we do suggest that this study paves the way for its use in the modelling of more exotic liquid crystals in complex geometries, obviating the need for complex numerical methods.

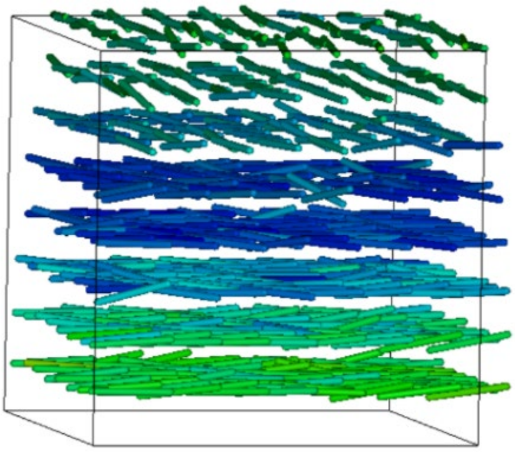

Figure 1. A snapshot of a twisted nematic cell from an MBDPD simulation.

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* Author for correspondence: guinan.zhao@postgrad.manchester.ac.uk

Optically Generated Microstructures in Diacrylate Polymer Networks Using a Two-Photon Initiating System

Wenjun. Zheng*, Zhi-Jie. Zhan, Meng-Yao. Su, and Tsung-Che. Ou

Department of Photonics, National Sun Yat-Sen University, 70 Lienhai Road, Kaohsiung 80424, ROC

Over the decades, there has been of great interest to manipulate microstructures into an optical medium to create appropriate photonic bands for molding the flow of light because of their value in fundamental studies and potential in an enormous range of technological applications [1]. In this case, two key issues are encountered: an appropriate material that allow the formation of desired structures in specific locations, and a practical means that can be utilized to complete related processing.

Recently, we used a crosslinkable diacrylate mesogen RM257 (E. Merck) as reactive monomers, and an optical interferomatric rig comprising a HeNe laser, which produces a 12 mW 632.8 nm continuous mode (CM) beam, as processing equipment (Figure 1). Our attention was caught by the diacrylate resins for its large third order nonlinear coefficients and capability in two-photon absorption [2]. We demonstrate here that the exposure of a thin layer of the diacrylate resin at an elevated temperature, at which the resin is in the nematic phase or becomes an isotropic medium, to an optical holographic pattern produced by means of multi-beam interference results in the formation of a layer of crosslinked polymer which contains patterned microstructures (Figure 2). The microstructures in the resultant polymer layer were generated due to a change in local molecular ordering, and the pattern of the localized structures was locked up following the polymerization of the diacrylate resin. The crosslinking of diacrylate resin was initiated via two-photon absorption. In this process, the holographic irradiation acted double as the driving force for the alignment of mesogenic groups in the diacrylate resin and the optical source that provided photons with desired energy for two-photon initiating the crosslinking of acrylate units. The significance of the present studies is that it might pave a way for the in situ fabrication of photonic circuit elements.

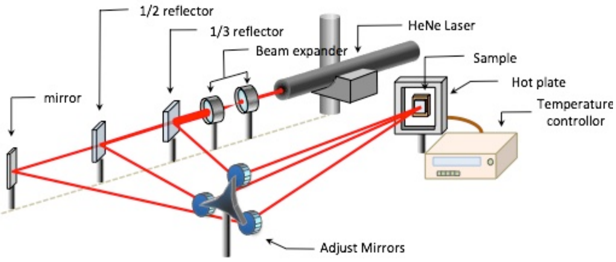

Figure 1 A schematic diagram showing the optical rig used in the present studies.

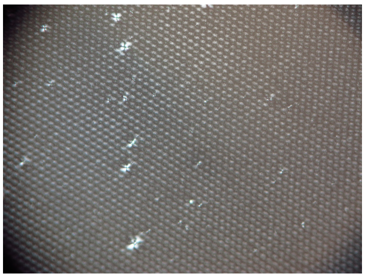

Figure 2 A photomicroscopic image of the localized structures generated in a diacrylate polymer using a three-beam interferometry.

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* Author for Correspondence: wzheng@ymail.com

Poster Contributions

Near-edge X-ray absorption spectroscopy in a ferroelectric nematic liquid crystal

Fumito Araoka[1*], Hiroya Nishikawa[1], Yoichi Takanishi[2], Hiroshi Iwayama[3,4]

[1]RIKEN Center for Emergent Matter Science (CEMS), Wako, Saitama 351-0198, Japan
[2]Faculty of Science, Kyoto University, Sakyo, Kyoto 606-8502, Japan
[3]UVSOR Synchrotron Facility, Institute for Molecular Science, Okazaki, Aichi 444-8585, Japan
[4]School of Physical Sciences, The Graduate University for Advanced Studies (SOKENDAI), Okazaki, Aichi 444-8585, Japan

Ferroelectric nematics (N_F) are a new group of polar fluid liquid crystals (LCs) co-possessing liquid-like fluidity and ferroelectricity. Although such a polar order state was predicted by the well-known physicist, Max Born, in the early 20th century, it had not yet been realized until its discovery in 2017 by two independent groups [1,2]. Since then, it has attracted broad attention from the fundamental science to the potentials for novel applications. One of the most fascinating physical properties of N_F is efficient generation of optical second harmonics, which is ~100 times larger than quartz, originating from efficient polar ordering in the present system. Recently, we reported cybotactic cluster formation stabilizing the N_F phase in diastereomeric DIO mixtures [3]. In this case, anisotropy of the smectic clusters, estimated from small/wide angle X-ray analysis, clearly shows fatting of clusters as temperature decreases. This suggests a possibility that side-by-side interaction may be an important role in stabilizing the polar ordering of the NF phase.

In this study, we performed near-edge X-ray absorption spectroscopy for the N_F liquid crystal, DIO. The carbon K-edge absorption spectrum was taken by scanning the photon energy of the soft X-ray irradiated on the sample sandwiched between two silicon nitride membrane films. The spectrum shows two signature peaks; one appearing in the lowest photon energy (~286eV) is corresponding to the π-electrons in the molecule, the other (~288.5eV) to the σ-electrons. Interestingly, the latter shows notable peak shift at the phase transition temperature from the N (SmZ_A) to N_F phases, while the former shows almost no change. This means, the head-to-tail dipolar interaction, which affects the longitudinal σ-orbitals, is stronger than the effect of the side-by-side attraction contributed from the π-π interaction. This was also discussed using theoretical computation of the near-edge X-ray absorption with a widely-used software package for NEXAFS analysis, StoBe. More details will be discussed in the presentation.

Acknowledgement: This work was supported by UVSOR (subject number: 23IMS6614, 22IMS6811).

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* Author for Correspondence: fumito.araoka@riken.jp

Spectral and Polarization Shaping of a Broadband Light Beam by Electrically Controlled Liquid Crystal Systems

Biagio Audia[1*], Pasquale Pagliusi[1,2], Alfredo Mazzulla[2], and Gabriella Cipparrone[1]

[1]Physics Department, University of Calabria, Rende 87036, CS, Italy
[2] CNR-Nanotec, c/o University of Calabria, Rende 87036, CS, Italy

Systems able to control multicolor light are of strategic interest in various applications, including spectroscopy, optical sensing, lighting and optical recording, display technologies and so on. Whitin this context, the capability to manipulate the spectral composition of broadband sources as well as the polarization state of each wavelength that compose them allows for improving spectral shaping and imaging, and for an enhancement of the sensitivity in detection devices and encoding rates. In this framework, we build up an electrically controlled system based on liquid crystal films, able to modify the spectral composition of a broadband light beam and independently, the polarization state of each spectral component. The system is based on two moduli, each one including an electrically tunable nematic liquid crystal cell. The first one includes a polarizer before and after the device that allows to modify the spectral composition by changing the applied voltage across the cell. At the exit of the second polarizer a second tunable liquid crystal film enables to control the polarization state. As proof of concept of the proposed approach the output beam of an Argon ion (Ar+) laser, operating in multiline configuration, with up to eight lines with different intensity and wavelength, has been spectral and polarization shaped to obtain the “depolarized” broadband beam reported in **Figure 1**.

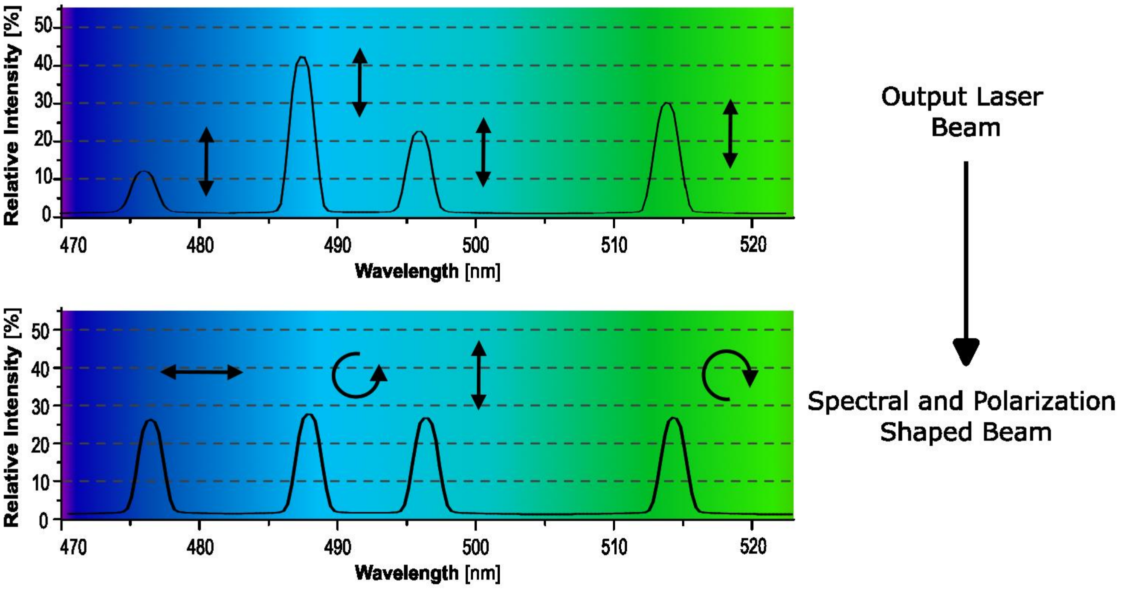

Figure 1: Spectral and polarization composition of the Ar+ broadband laser beam before (top) and after (down) the interaction with the two electrically tunable liquid crystal cells.

* Author for Correspondence: biagio.audia@unical.it

Multi-stimuli optical responsiveness of fluorenoviologen liquid crystals

Giuseppina Anna Corrente[1], Agostina Lina Capodilupo[2], Gianluca Accorsi[2], Francesca Scarpelli[1], Alessandra Crispini[1], and Amerigo Beneduci[1*]

[1]Department of Chemistry and Chemical Technologies, University of Calabria, Rende 87036, CS, Italy
[2]CNR-Nanotec, Institute of Nanotechnology, Campus Ecoteckne, Via Monteroni, Lecce 73100, Italy

Materials exhibiting tunable optical absorption/fluorescence properties upon the simultaneous application of different external stimuli, providing a readable corresponding signal, have received great scientific attention for their potential applications in wearable electronics, anticounterfeiting, self-powered light sources and displays, human-machine interactive systems, intelligent sensing systems [1-5]. A very promising strategy to afford multi-stimuli optical responsiveness in a material is to combine several functionalities in one structure e.g., reversible electrochemistry, ion and electronic charge transport, photoluminescence, and supramolecular organization like mesomorphism [6-10]. Here we present a new class of thermotropic smectic ionic liquid crystals consisting of the bistriflimide salts of π-conjugated fluorenoviologens dications whose rigid core is decorated at the N terminals by promesogenic alkyl chains of different length (Figure 1a). In the bulk liquid crystalline phases, they exhibit On/Off electrofluorochromism (UV photoexcitation) with a voltage-induced fluorescence quenching (Figure 1b) and yellow to dark electrochromism (Figure 1c). In addition, they are also thermofluorochromic with huge color change of the fluorescence from green to blue as the materials are brought from the room temperature crystalline phase to the liquid crystalline phases at higher T (Figure 1d).

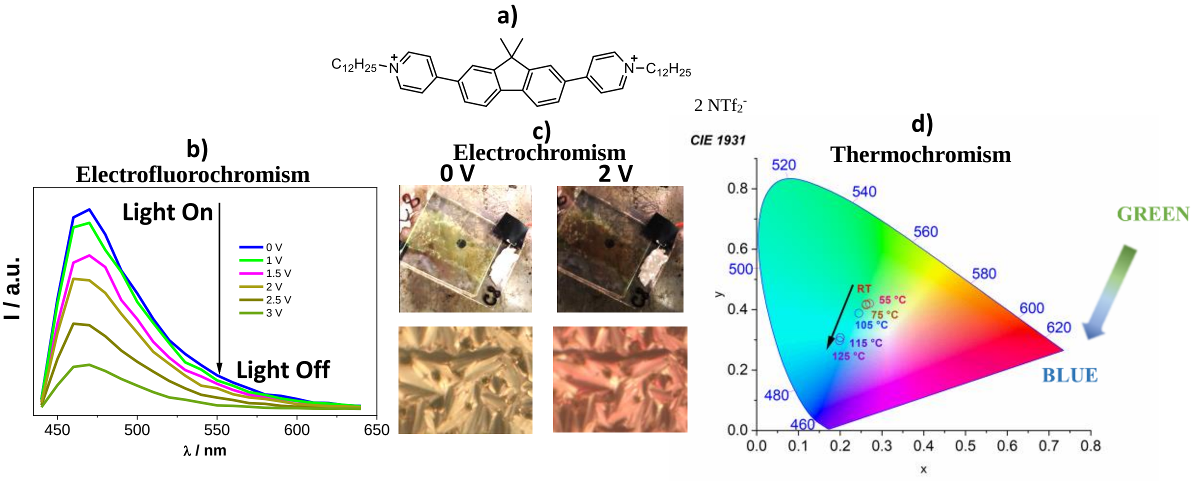

Figure 1. a) Chemical structure of the liquid crystalline compound 12FV(NTf_2). Optical response of a thin film (5 µm) of the fluorenoviologen 8FV(NTf_2) sandwiched between two Indium-Tin-Oxide glass substrates, upon the application of photo, electro and thermal stimuli: b) electrofluorochromism; c) electrochromism and d) thermofluorochromism.

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* Author for Correspondence: amerigo.beneduci@unical.it

Application of the Catastrophe Theory to Description of the Phase Transition Mechanism in Nematic Liquid Crystal Systems

L.S. Bezhanova*

Institute of Applied Problems of Physics NAS Armenia, 25 Hr. Nersisyan Str., Yerevan 0014, Armenia

Building upon our previous investigations into the dynamic processes involved in phase transitions and structural transformations in nematic liquid crystal (NLC) systems [1,2], this study explores the application of catastrophe theory to describe the molecular mechanism of smectisation and the regulation of polymorphism in NLC systems. We have identified a relationship between the control variables of cusp catastrophe and the smectic order parameter of NLC systems.

Detailed analysis of UV and IR spectra, along with comparison to the results of EPR data [2-6], has allowed us to identify at least five types of particles (monomers and a few percent associates of donor and acceptor, CTC of DA and D_2A types) in NLC systems at a given temperature and pressure. Thus, we conducted thermodynamic potential minimization not only in terms of structural degrees of freedom, but also in terms of the molecular composition of NLC systems, in order to better understand the role of various types of intermolecular interactions in the process of polymorphism.

According to [7], considering the interaction of nematic and smectic order parameters [8] as well as using the material balance equation [9], for the thermodynamic potential $\phi(x; a, b)$ we have:

$$\phi = -\frac{1}{2}\chi C^2\eta^4 + p\eta^3 + q\eta^2 + m\eta + \xi \tag{1}$$

where η is order parameter of the LC; χ is response function; C is a positive constant; p, q, m and ξ are determined by the equilibrium constants K_1 and K_2 of the DA and D_2A CTC; by the number of solvent molecules, the number of molecules of the i- component of the LC system; by the pressure and temperature of the system. Excluding the cubic term in (1) by replacing $x = \eta - \frac{p}{2\chi C^2}$, equation will be rewritten as: $\phi = \frac{1}{4}x^4 + \frac{1}{2}ax^2 + bx + c$, where $a = \left(q - \frac{3}{2}p^2\right)$ and $b = 2p^3 - 2pq + m$. Shifting the energy reference point we can put $c = 0$. Then for ϕ we finally get:

$$\phi = \frac{1}{4}x^4 + \frac{1}{2}ax^2 + bx \tag{2}$$

Expression (2) becomes the characteristic equation for the cusp catastrophe [10]. (a, b) are the coordinates on the control space. Vertical coordinate x is internal variable and is determined by the η order parameter. Now for any pair of control variables the critical values of expression (2) will be determined from the equation $\frac{\partial\phi}{\partial x} = 0$, which is the equation for the equilibrium surface:

$$x^3 + ax + b = 0 \tag{3}$$

This equation makes the study of structural transitions in NLC system possible using the analysis of the critical points of $\phi(x; a, b)$ function. As the control (a, b) variables vary, a local minimum can disappear and the internal variable can suddenly jump to a different equilibrium state. Also the state $(x; a, b)$ will be forced to jump to the other sheet when it crosses the fold curve (Fig. 1). The bifurcation set is the critical image of the projection $(x; a, b)$ from the equilibrium surface onto the control space (a, b).

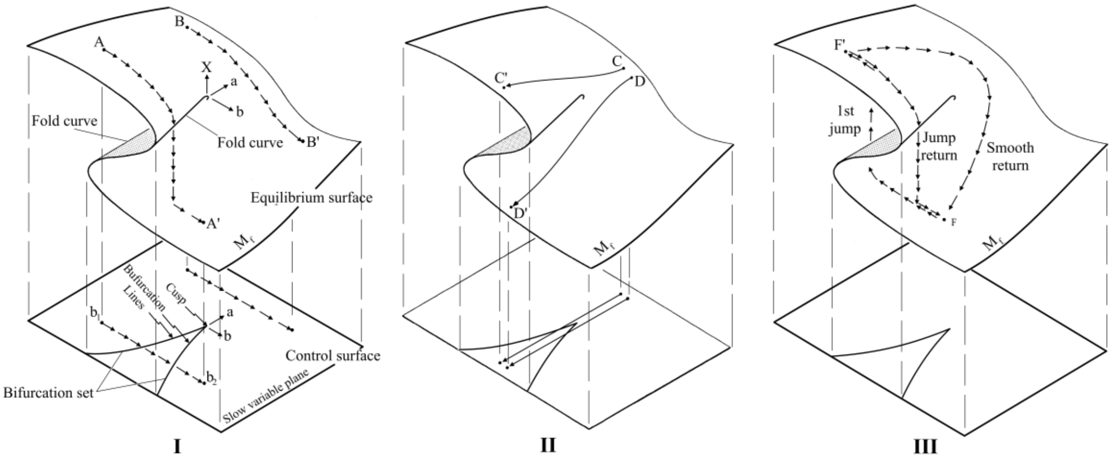

Figure 1. The equilibrium surface of the binary nematic liquid system in the $(x; a, b)$ space and the mapping of the manifold onto the (a, b) space. Cusp catastrophe manifold: a and b are control parameters and x is the variable. I - b goes from b_1 to b_2 : if $a < 0$, there is a catastrophic jump at the point, where the AA' state trajectory becomes tangent to the x- axis; if $a > o$, BB' path does not cross singularity and thus avoids the fast jump. II – if a is reduced to a negative value, the two nearby states C and D end up at the widely separated final states C' and D'. III – jump return to the cusp manifold, as well as a way to obtain a smooth return by going around the cusp on the return from F' to F.

On the other hand, the equilibrium state of Sm phase at given temperature and pressure ultimately determined by the equilibrium constants K_1, K_2 (control variables) of the DA and D_2A type CTC. Thanks to the catastrophe theory it was possible to evaluate the area of K_1,K_2change which allows system to remain in sustainable state. That is by controlling the value of K_1, K_2 it is possible to regulate the process of polymorphism in NLC systems. An important circumstance is the role of the control variables, a smooth change of which can lead to a jump-like change in the functionality of the system. The catastrophe theory at a sufficiently high level allows determining the scope of changing control variables and thereby ensure the operability of the device.

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[*] L.S. Bezhanova: libezhanova@gmail.com

Towards environmentally friendly techniques for manufacturing PUF key based anticounterfeiting labels.

Mauro Daniel Luigi Bruno[1,2], Erica Fuoco[1,2], Gia Petriashvili[3], Antonio Ferraro[2], Giovanna Palermo[1,2], Riccardo Cristoforo Barberi[1,2], Alberto Belmonte Parra[4], Cees W. M. Bastianseen[4], Albert Schenning[4] and Maria Penelope De Santo[1,2]

[1]Physics Department, University of Calabria, Rende 87036, CS, Italy
[2] CNR-Nanotec, c/o University of Calabria, Rende 87036, CS, Italy
[3] Institute of Cybernetics of the Georgian Technical University,
Z. Anjaparidze 5, 0186, Tbilisi, Georgia
[4]Stimuli-Responsive Functional Materials and Devices, Eindhoven University of Technology 5600 MB
Eindhoven, The Netherlands

Recently, the interest for the fabrication of anti-counterfeiting label based on PUF (Physical Unclonable Function) paradigm is growing. A PUF key is an object produced through a non-deterministic process, impossible to clone and reproduce [1]. Among the best candidates for anti-counterfeiting label fabrication, we can find liquid crystals, especially cholesteric liquid crystals (CLC). These materials possess peculiar optical properties and when confined in micrometric spheres show a plethora of textures that can be tune as a function of external electric fields [2], temperature and mechanical stresses. Here, we present different techniques that allow us to obtain random optical patterns that can be used as PUF keys and that can be easily implemented in an anti-counterfeiting device.

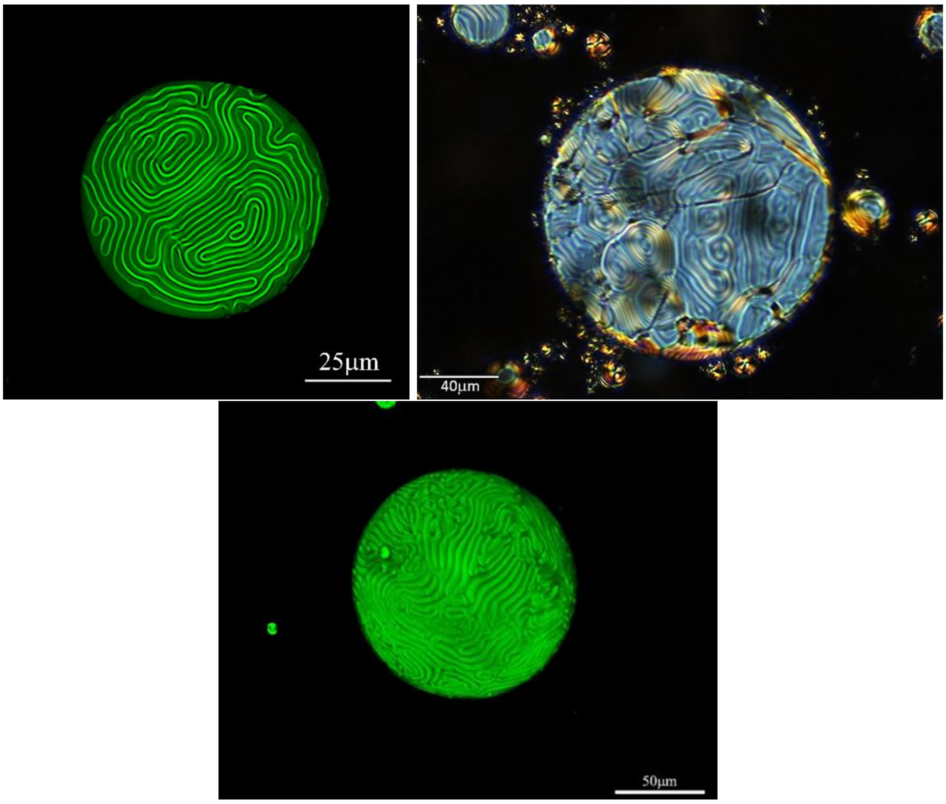

Figure 1. Microfingerprint-like texture in a CLC microdroplets obtained as a function of externals electri field (a), temperature (b) and mechanical stress (c).

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* Author for Correspondence: bruno.mauro89@gmail.com

Surface-like elastic constants of liquid crystal: elusive or illusive?

Davide Revignas and Alberta Ferrarini[*]

Department of Chemical Sciences, University of Padova, Padova 35131, Italy

The elastic behavior of nematics is commonly described in terms of the three so-called bulk deformation modes, i.e. splay, twist and bend. However, the elastic free energy [1,2] contains two additional terms, which are denoted as saddle-splay and splay-bend, respectively, and often are collectively referred to as surface-like. These terms contribute, for instance, in confined systems; yet, they are controversial, partly because of the difficulty of their experimental determination [3]. The saddle-splay (K_{24}) and splay-bend (K_{13}) elastic constants remain elusive also for theories; indeed, even the possibility of obtaining unambiguous microscopic expressions for these quantities has been debated [4,5].

Within the framework of Onsager theory [6] with Parsons-Lee correction [7], we have obtained microscopic estimates of the deformation free energy of hard rod nematics in the presence of different director deformations [8,9]. In the limit of a slowly changing director, these can be directly compared with the continuum elastic free energy. Within the same framework, we have obtained also closed microscopic expressions for all elastic coefficients of rodlike nematics. We have found that the saddle-splay constant K_{24} is larger than both K_{11} and K_{22} over a wide range of particle lengths and densities. Moreover, K_{13} has been found to be crucial for the consistency of the results obtained for different director distortions. The implications of such results will be discussed, also in the light of recent experimental findings [10,11], which have raised questions on the thermodynamics stability of the uniform nematic state [12,13].

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* Author for Correspondence: alberta.ferrarini@unipd.it

Random system based on soft matter to create anti-counterfeiting devices

Erica Fuoco[1,2] *, Giorgia Mammoliti[1], Riccardo Barberi[1,2], Maria Penelope De Santo[1,2]

[1]Physics Department, University of Calabria, Rende 87036, CS, Italy
[2] CNR-Nanotec, c/o University of Calabria, Rende 87036, CS, Italy

Novel anti-counterfeiting systems are based on physical unclonable functions (PUFs) [1]. A PUF tag is a new paradigm for authentication, identification and traceability of goods and it could be a physical object that is generated in a random way and hard to duplicate.
Soft materials and, in particular, liquid crystals (LCs) able to self-assemble in complex optical structures, are the ideal candidates for the creation of PUF keys [2].
We propose a novel anti-counterfeiting device based on the optical properties of thermotropic chiral LCs and dye-doped nematic LCs (DD-LCs) combined in a random way to generate a PUF key. The tunable thermochromatic and fluorescence properties of LCs were studied with the materials in planar and spherical confinement.

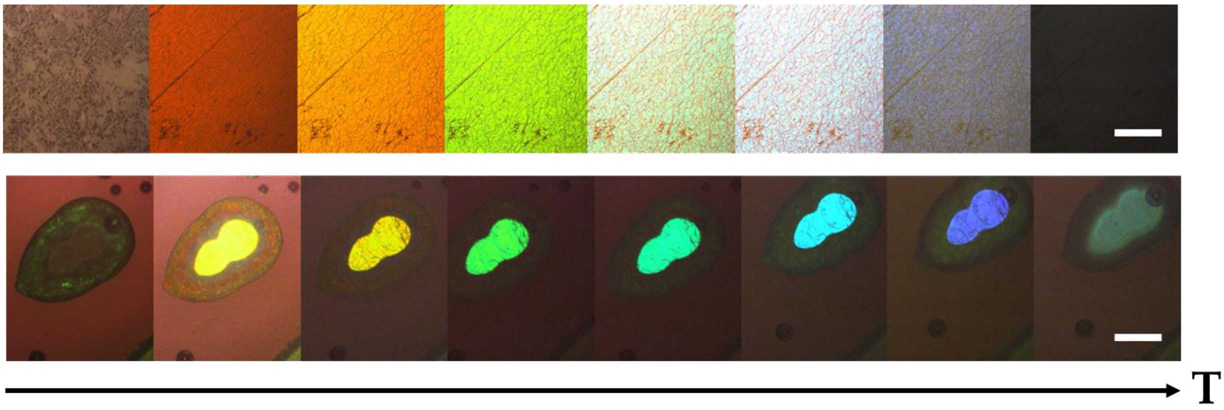

Figure 1. Polarized light microscopy transmission image of an optical cell containing a chiral LC in planar anchoring conditions (top) and in LC droplets in a PVA/water emulsion (bottom). The temperature increases from left to right. Scale bar 500µm

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* Author for Correspondence: ericafuoco@hotmail.it

Reconfigurable Liquid Crystal Beam Expander

Javier Pereiro-García[1], Byron Ganazhapa[1], Pablo de la Rosa[1,2], Morten A. Geday[1*], José M. Otón[1], Manuel Caño-García[1]

[1]CEMDATIC, ETSI Telecomunicación, Universidad Politécnica de Madrid, Av. Complutense 30, 28040 Madrid, Spain
[2]GEA, ETSI Telecomunicación, Universidad Politécnica de Madrid, Av. Complutense 30, 28040 Madrid, Spain

Beam expanders (BE) are optical systems that modify the diameter and angular aperture of beams. The simplest configurations consist of two confocal lenses. The lenses can be both convergent (Keplerian BE) or one divergent and one convergent (Galilean BE). In the Keplerian model, the distance between lenses is the sum of the focal distances. In the Galilean model, the distance between lenses is the difference between the (absolute) focal distances.

It gathers that Galilean BEs are shorter than Keplerian BEs for the same lens size and expansion power. Moreover, the beam is inverted in the Keplerian BE not in the Galilean BE. However, Keplerian BEs have their own advantages as well: there is a focal point inside the device that can be used to spatially filter the beam.

In either case, the diameter of the expanded beam can be only controlled by varying the distance of the output lens to the focus, what implies substituting the lens by other having the corresponding focal distance. Alternatively [1], one can use systems with three lenses whose distances are mechanically modified.

A reconfigurable beam expander with no movable parts based on liquid crystal (LC) lenses has been realized. Adaptive spiral diffractive LC lenses developed in our lab [2] have been used. The LC lenses employed in this design can be switched between 36 positive and 36 negative configurations, *i.e.*, convergent or divergent lenses, with powers running between ±0.17 and ±6 diopters. Both, Keplerian and Galilean configurations can be set up. The lenses are driven by means of an in-house customized electronic control driver. A non-photolithographic process for lens manufacturing has been achieved by ablation of ITO coated glass substrates using Direct Laser Writing. Cells were eventually filled in with a high birefringence nematic LC (MDA 98-1602).

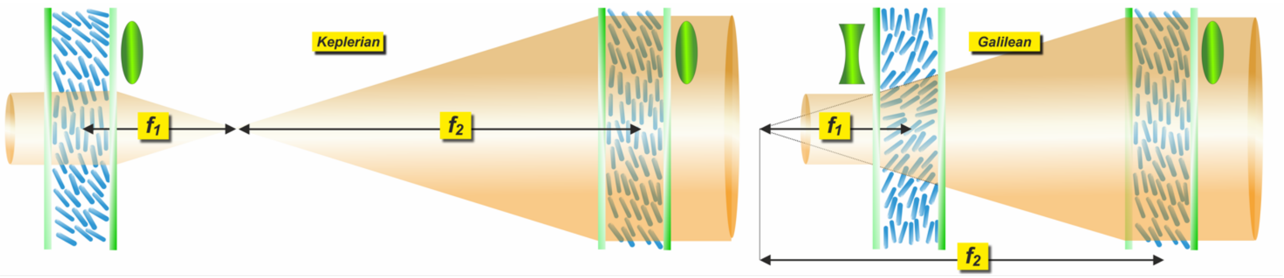

Figure 1. Tunable Keplerian and Galilean Beam Expander setups based on LCs. Keplerian configuration comprises two convergent lenses whereas Galilean configuration comprises one convergent lens and one divergent lens.

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* Author for Correspondence: morten.geday@upm.es

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Cholesteric liquid crystal as a template for nanoparticle control

Ines Gharbi[1,2*], Habib Ayeb[2], Randall D. Kamien[3] and Emmanuelle Lacaze[1]

[1]Sorbonne Université, CNRS, Institut des Nanosciences de Paris, INSP, Paris F-75005, France
[2] Faculté des Sciences de Tunis, LR99ES16 Physique de la Matière Molle et de la Modélisation Electromagnétique, Université de Tunis El Manar, Tunis 2092, Tunisie
[3]Department of Physics and Astronomy, University of Pennsylvania, Philadelphia 19104, Pennsylvania, United States

The cholesteric liquid crystal modulation texture, which may seem ordinary at first sight, is capable of microscale organization of nanoparticles that are deposited on its surface. This organization mimics the cholesteric undulations obtained by the deformation of the liquid crystal by external parameters. By controlling the organization of nanoparticles we can change their optical properties [1], and this can find technological applications. Control over the organization of nanoparticles can be obtained by understanding their self-organization at the nanoparticle scale, which is related to the elastic deformations of the cholesteric and the deformations generated by the interactions between the nanoparticles and liquid crystal [2].

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* Author for Correspondence: ines.gharbi01@gmail.com

Hybrid Nanosystems Based on Silver Nanoparticles with Cholesteric Ligands: Physico-Chemical Properties and DFT-modeling.

Gromova Ya.A.[1]*, Ermilov A.Yu.[1], Shabatina T.I.[1]

[1]Lomonosov Moscow State University, Department of Chemistry, 119991, Leninskie Gori 1/3, Moscow, Russian Federation

Hybrid nanosystems based on stabilized silver nanoparticles (SNPs) attract the attention of researchers due to their unique optical, structural, morphological, mesogenic, adsorption properties. Atoms and small clusters obtained as a beam using thermal evaporation of bulk metal under high vacuum conditions and followed by condensation on cooled support surfaces of different preparative cryostats possess a high chemical reactivity as compared to that of bulk metals. SNPs with size of 2-3 nm can interact with cholesteric molecules forming hybrid linear aggregates (length 10 μ) which possess plasmonic collective absorbtion in the visible range of wavelengths. Cholesterol is an important biomolecule and an essential component of most biological membranes and serves functions in controlling membrane integrity, organization and signaling. Moreover cholesterol and it’s derivatives thiocholesterol have unique liquid crystalline properties. The use of hybrid nanosystems based on SNPs-cholesterol and SNPs-thiocholesterol opens up new and promising ways for research. One of them is using such systems in direct drug delivery. It’s well known that SNPs have a strong antibacterial properties. Stabilization of SNPs with mesogenic liquid crystalline molecules leads to the formation of small spherical particles with average size (5.5±1.0) nm in case of cholesterol and (2.7±0.6) nm in case of thiocholesterol. This approach allows to use such systems for targeted drug delivery improving bioavailability and efficiency. Moreover the practical interest to these systems stimulates the need for theoretical modeling developing primarily with modern quantum-chemical calculations.

The aim of this work is obtaining of hybrid nanosystems based on SNPs stabilized by cholesterol and thiocholesterol and studying of their physico-chemical properties. Stabilized SNPs were prepared by two methods: classical chemical reduction from $AgNO_3$ with further stabilization and cryoformation at low temperature. The results of quantum chemical calculations confirmed that thiocholesterol is the strongest stabilizing ligand for SNPs. SNPs stabilized by thiocholesterol have an intense plasmon absorption band at 470 nm. The results of differential scanning calorimetry (DSC) in combination with polarization optical microscopy data showed the formation of cholesteric mesophase in this nanosystems. The results of circular dichroism spectroscopy (CD) confirmed the presence of optical activity in this hybrid nanosystem.

Besides stabilized SNPs can be used as a model for detecting processes in cell membranes, selective adsorbents, stationary phases for separation of optically active compounds and drug delivery.

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* Author for correspondence: chemyaninka@mail.ru

Photosensitive Liquid Crystals Applicable in Gas Sensors

Barbora Jansová[1,2]*, Michal Šmahel[1], Michal Kohout,[1#] Marcel Bouvet,[2#] Vladimíra Novotná[3]

[1]Department of Organic Chemistry, UCT, Technická 5, Prague 16628, Czech Republic
[2]ICMUB, University of Burgundy, 9 Av. Alain Savary, Dijon 21000, France
[3]Institute of Physics, Czech Academy of Science, Na Slovance 2, Prague 18221, Czech Republic

Liquid crystals (LCs) opened an exciting new research area seeking applications beyond the display technology, in nonlinear optics and photonics, drug delivery systems and sensors, among others. The LCs interact with several different classes of molecules, including surface-active agents such as lipids and surfactants, and non-surface-active agents such as gas vapors, and can be tailored to respond only to specific antigens. Notably, the innate fragility of the mesophases and their inherent sensitivity to various external stimuli offer intriguing sensor applications [1]. The envisioned LC-based sensors demonstrate significant advantages over the established technologies, *e.g.*, solution processability, polymer encapsulation and simple drop casting techniques for thin layer deposition. In addition, the design of responsive coatings has gained increasing attention recently, with light responsive interfaces receiving particular attention, as their surface properties can be modulated with spatiotemporal control. Despite the outlined benefits, the use of LCs in molecular sensors is strikingly underinvestigated.

The advanced self-assembling systems show a promising strategy to enhance gas-sensing properties by modulation of charge transport of an organic heterojunction sensor. The heterojunction sensors have been fabricated by depositing sequentially molecular semiconductor and lutetium bis-phthalocyanine thin films in a bilayer configuration on ITO interdigitated electrodes (IDE) [2]. The organic heterojunction effect, causing accumulation of mobile charge carriers at the organic-organic interface, results in the enhancement of interfacial conductivity that can be exploited to fasten the charge transfer during gas-sensing material interaction [3]. Ammonia sensing have been studied in a dynamic way, alternating exposure/recovery periods (10 min/30 min or 1 min/4 min).

Hereby, this study deals with the synthesis of new bent-shaped LCs based on previously established central unit [4,5] and presents a subsequent study of their application in electronic organic devices based on ITO IDE (Figure 1). New bent-core LCs have been designed and synthesised. With the aim to tune properties of the nematic phase, the type of the linking unit in the lengthening arm was varied with rising rigidity from benzoate ester, biphenyl to azo moieties. Among them, the azo group stands out for its chemical stability and the distinct conditions of photoisomerization. Additionally, the structures of all new bent-core liquid crystals and their intermediates were confirmed by ^{1}H and ^{13}C NMR spectroscopy. DSC and POM studies were further performed to determine the mesomorphic properties of the studied materials. Subsequently, new heterostructures consisting of a bilayer assembly of light-responsive LCs and $LuPc_2$ have been investigated for ammonia sensor development. The electrical properties of the devices were characterized by I-V measurements. The curves showed a non-linear behavior due to a heterojunction effect between both layers. Ammonia sensing studies have been performed giving response curves at successive exposures with NH_3 concentration in the range of 10-90 ppm for the three sensors. Generally, according to the current decrease under NH_3 the devices demonstrate the p-type behavior (Figure 2).

P 15

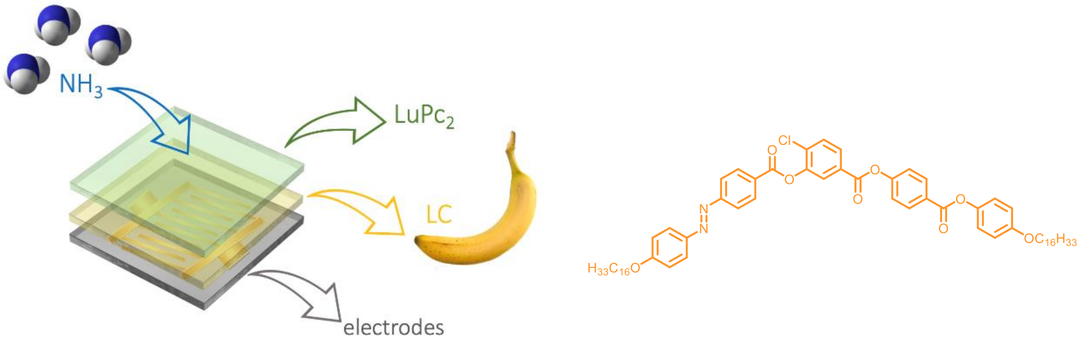

Figure 1. Schematic view of a molecular bilayer heterojunction on ITO IDE.

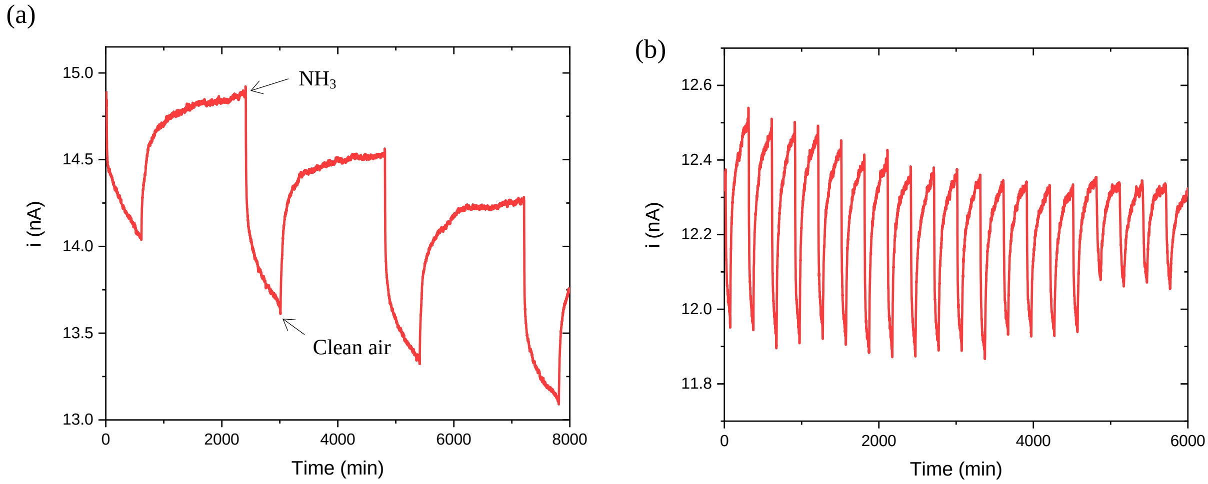

Figure 2. Response curves of LCs/LuPc$_2$ heterojunction device obtained at 4 successive exposures to 90 ppm of NH$_3$ (10 min) and recovery under clean air (30 min) (a); and short exposure/recovery cycles (1 min/4 min) at five different NH$_3$ concentrations (90, 70, 50, 30 and 10 ppm) (b); applied bias 3 V, RH 45 %.

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* Author for Correspondence: jansovabarbora@gmail.com
# Supervisors

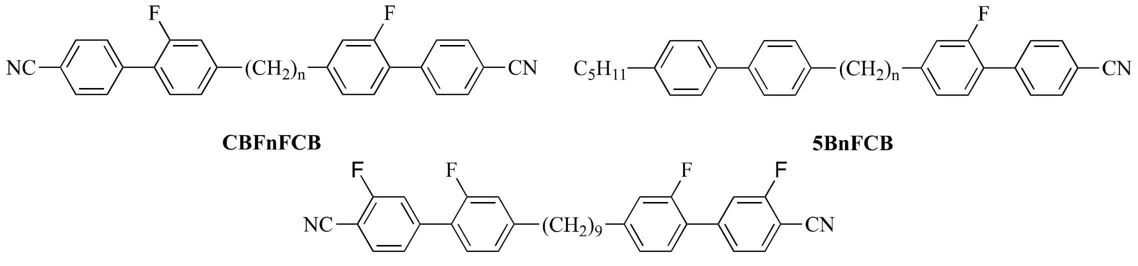
Synthesis and properties of fluorinated liquid crystal dimers

Jakub Karcz[1*], Jakub Herman[1], and Przemysław Kula[1]

[1]Institute of Chemistry, Faculty of Advanced Technologies and Chemistry, Military University of Technology, Warsaw, Poland

Liquid crystal dimers are known for creating the chiral structure from achiral molecules [1]. This behaviour was predicted by Dozov and Meyer independently, who suggested that bend shape compounds can form a helical nematic structure. However, space cannot be filled by molecules with pure bend deformation, so together with accompanying twist deformation twist-bend nematic (N_{TB}) phase is created [2,3]. Since the first discovery of the N_{TB} phase [4], plenty of new materials have been reported. The lateral substitution of such materials, especially with fluorine atoms, is strongly dependent on the type of connection between molecular cores and flexible spacers.

Based on the archetypal CBnCB materials, we have designed two independent synthetic routes for synthesis of N_{TB} materials bearing a fluorine atom in the inner phenyl rings. The methods differ in a way of connecting mesogenic units with the flexible spacer. The first one is based on the cross-coupling reaction involving Grignard reagents, while the second one uses phenylacetylide ions in S_N2 carbon-carbon bond formation. The Figure 1 presents the general structures of investigated materials.



CBFnFCB

5BnFCB

CFBF9FCFB

Figure 1. General structures of designed N_{TB} materials.

Based on the designed synthetic routes, nine new dimeric molecules were obtained: four from **CBFnFCB** series, four from **5BnFCB** series and one **CFBF9FCFB** compound. They exhibit strong fluorination originated dependence as well as flexible spacer length-properties dependence. New compounds were compared to the CBnCB series, exhibiting lower phase transition temperatures and a wider N_{TB} phase range.

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* Author for Correspondence: jakub.karcz@wat.edu.pl

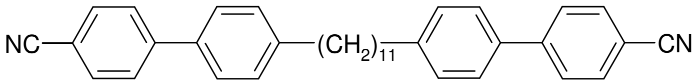
Miscibility studies of liquid crystal cyanobiphenyls with CB11CB forming nematic twist bend phase

Barbara Klucznik*, Marzena Tykarska

Institute of Chemistry, Military University of Technology, Warsaw, Poland

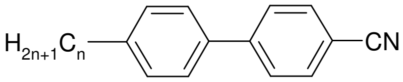
In 2011 the existence of a twist bend nematic phase (N_{TB}) was confirmed [1]. Till now this phase is intensively studied mostly in order to search for new structures allowing formation of such phase [2,3]. The N_{TB} phase is usually monotropic phase because of high melting points of pure compounds. That fact causes problems with examination of N_{TB} phase. Preparation of mixtures can be a way to lower the melting point and broaden the temperature range in which the N_{TB} phase is enantiotropic. There are only few examples of miscibility studies in binary systems where only one component exhibits N_{TB} phase [4-6].

The aim of this study is to investigate bicomponent systems in which compound CB11CB (Figure 1) forming N_{TB} phase is dopped with different cyanobiphenyls (nCB, n=3-5,7-12,14) in order to test their influence on the melting points and temperature range of N_{TB} phase. It was found that the N_{TB} phase is supported in mixtures in wide concentration range and it is observed up to 0.6-0.7 mole ratio for most systems. Unfortunately the melting temperature is not depressed much thus the N_{TB} phase is still mostly monotropic in mixtures.



CB11CB

Cr 99.9 N_{TB} 108.6 Iso 125.5 [7]



nCB [8]

Figure 1. Structure tested compounds

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* Author for Correspondence: barbara.klucznik@wat.edu.pl

Insights into the computational calculations and properties of liquid crystals

Rohit Lalka,[1] Virender,[2] Suresh Kumar,[3*]

[1]Department of Computer Science and Advanced Studies, Gyan Ganga Polytechnic, Kurukshetra, 136119, Haryana, India
[2]Department of Chemistry and Material Science, Kurukshetra University, Kurukshetra, 136119, Haryana, India
[3]Department of Higher Education, Shaheed Udham Singh Govt College Matak Majri, Karnal, 132041 Haryana, India

The computational studies of liquid crystals with the insightful discussion of structural and electronic properties can help in designing new devices [1,2]. In addition, the studies of complex macromolecular liquid crystals can provide valuable information for optoelectronic devices. Herein this poster, we have discussed the computational insights into the material properties such as molecular dynamics simulation and time-dependent density functional theory (TDFT) calculations. The study also points to the recent report and outcomes of liquid crystals and complexes. In addition, the determination and optimization of liquid molecular structure are discussed, which can help to find the physicochemical properties in liquid crystals. Furthermore, the molecular dynamic simulation and TDFT calculations provide sufficient information regarding the solutions' optoelectronic properties and energy.

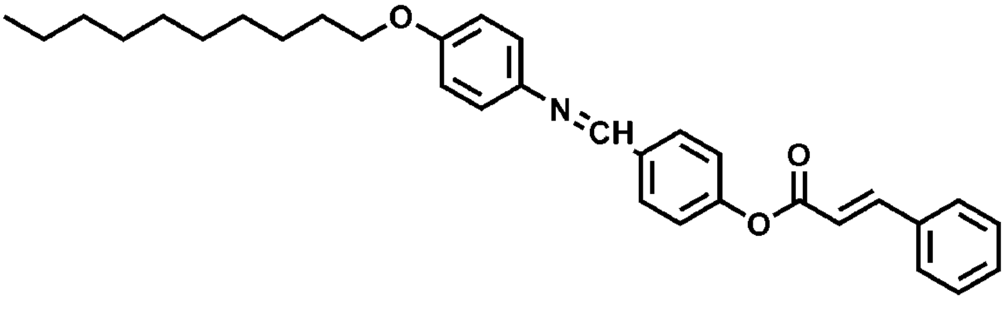

Figure 1. Typical liquid crystal molecules used in the study.

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* Author for Correspondence: gcmatakmajri@kuk.ac.in

Ferroelectric nematic phase in materials with nitrogen-based electron donating group: A synthetic study

Tomáš Landovský[1*], Martin Cigl[1], Natalia Podoliak[1] and Vladimíra Novotná[1]

[1]Institute of Physics of the Czech Academy of Sciences,
Na Slovance 2, 182 00 Prague 8, Czech Republic

Within a few years from the discovery of the ferroelectric nematic phase [1, 2], this field has gained a considerable attention, due to its enormous technological potential in advanced functional electrooptical devices. Recently, the first guidelines for the molecular design of materials exhibiting N_F were formed [3], requiring a high dipole moment value of the molecule, suitable aspect ratio, length of the molecule as well as the dipolar angle. Considering these limitations, we have designed and synthesized a new molecular structure that shows N_F phase on the cooling process from the isotropic phase [4]. The uniqueness of our structure lies in the presence of the nitrogen-based electron donating group (EDG) which increases the overall dipole moment significantly.

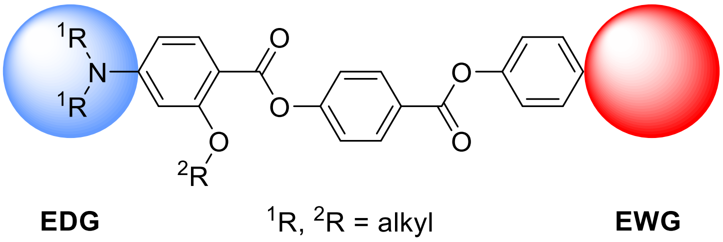

Figure 1. General structure of new materials with nitrogen-based EDGs

In this contribution, we present various synthetic approaches to a series of nematogens based on our structure motif (Figure 1). The ferroelectric behaviour of this series was investigated by the combination of dielectric spectroscopy, second harmonic generation, polarization current measurements and by the analyses of textures in the polarized light. Moreover, the syntheses and mesogenic properties of further derivatives, using adjusted nitrogen-based EDGs and/or different electron withdrawing groups (EWGs) are also discussed.

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[*] Author for Correspondence: landovsky@fzu.cz

Fabrication of liquid crystal devices to prevent information leakage and counterfeiting

Jae Hoon Lee[1], Hyeon-Ji Son[1], Jeong-Seon Yu[2] and Jong-Hyun Kim[1,2*]

[1] Department of Physics, Chungnam National University, Daejeon, Republic of Korea, 34134
[2] Institute of Quantum Systems, Chungnam National University, Daejeon, Republic of Korea, 34134

Counterfeit products are a growing concern for manufacturers and consumers, prompting the need for more robust anti-counterfeiting action [1]. This study describes the development of an anti-counterfeit security device that utilizes the elastic and optical properties of a liquid crystal (LC) [2]. The proposed LC device involves the personal pattern that can be used for certification using a photo-alignment. In order to use the pattern for authentication, it is available only by changing the phase of the LC [3]. When a phase transition from the smectic A to the nematic phase occurs, a hidden pattern appears. And return to the initial phase, the pattern is invisible, leaving a trace of the information. This trace allows responding simultaneously to the information leakage and subsequent counterfeits. It also adjusts the polarization angle of irradiation light. Then, even if hacking occurs, an optional secondary security element can be added by hiding the image or displaying a warning message.

The experimental results demonstrate the effectiveness of the devices in detecting counterfeit products, with easy manufacturing. This study shows the potential of LCs as materials for developing anti-counterfeiting devices with optical and elastic properties of the LC.

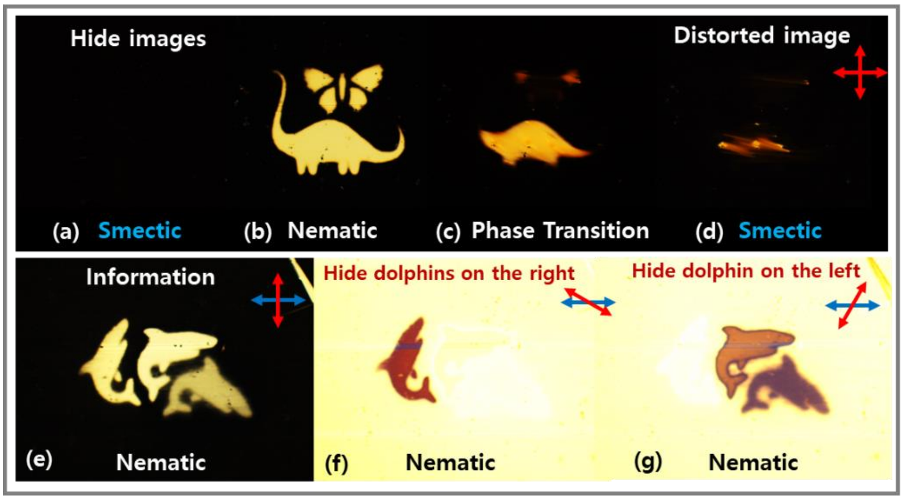

Figure 1. Experimental results on anti-counterfeit and security. (a) through (d) are the results of observing LC texture while changing the phase. The information can be confirmed only on the nematic phase of (b), and it can be seen that traces are left at the position of the pattern (information) when the phase transition to the smectic phase of (d) occurs. You can also display the exposed distorted image selectively. In (e) to (g), the angle of the polarizer and the analyzer can be adjusted to selectively hide the image even in the nematic phase.

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* Author for Correspondence: jxk97@cnu.ac.kr

The Dynamics of a Colloidal Particle with a Point Defect in Nematic Liquid Crystals Under Flow

Jun-Yong Lee[1, 2] and Jong-Hyun Kim[1, 2, *]

[1]Department of Physics, Chungnam National University, Daejeon 34134, Korea
[2] Institute of Quantum Systems, Chungnam National University, Daejeon 34134, Republic of Korea

In a nematic system, flow plays a significant role in affecting the alignment of the director [1]. Hence, the behavior of a topological defect can also be influenced. Many studies were interested in the behavior of a topological defect itself under flow, such as changes in form and position [2, 3]. In contrast, relatively rare studies focused on the effect of changes in a topological defect by flow on colloidal particles. This study focused on the motion of colloidal particles accompanying a hedgehog point defect suspended in nematic liquid crystals (NLCs) under flow.

We placed a spherical magnetic particle inducing a homeotropic alignment, which accompanies a hedgehog point defect, into uniformly aligned NLCs. Producing a regional flow by rotating the particle using a magnetic field, we observed the behavior of the particle and the accompanied point defect through a polarizing optical microscope.

While the point defect preferred to align parallel with the far-field director, the flow produced by the particle rotation tended to change the position of the point defect because the flow propagated perpendicular to the far-field director. We found the line from the center of the particle to the point defect to have a larger angle to the far-field director at a higher rotation frequency.

After the particle stopped rotating, the point defect returned to the initial angle parallel to the far-field director. In the process of the return, we observed that the particle moved, maintaining the center of mass of the particle and the point defect. From this, we found the point defect to act as if it possessed an effective mass compared to the particle mass.

We explained the above behaviors through calculations using a theoretical model. We expect this study offers significant help in comprehending the behavior of colloidal particles and topological defects under flow.

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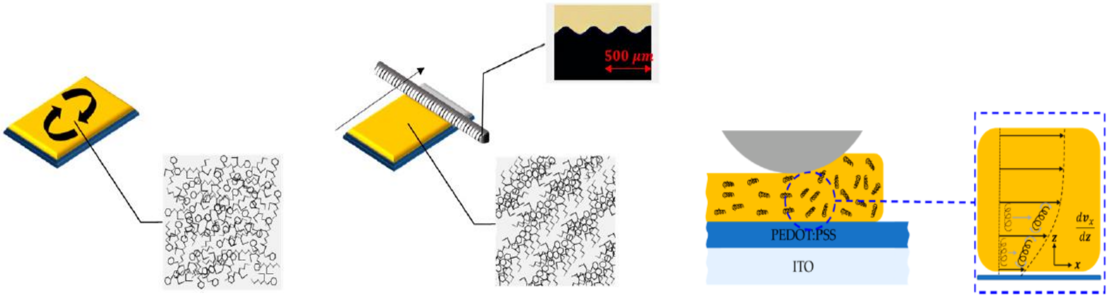
* Author for Correspondence: jxk97@cnu.ac.kr

Enhanced Electro-Optical Performance of Organic Light-Emitting Diode by Molecular Ordering of the Emission Layer

Seok Je Lee[1], Woo Young Kim[1], and Chul Gyu Jhun[1*]

[1]Department of Semiconductor Engineering, Hoseo University, Asan 31499, Korea

In this paper, we investigated the effects of molecular ordering on the performance of the organic light-emitting diode (OLED) device. The electro-optical effects due to the molecular ordering and the luminescence efficiency was also compared by analyses with various methods [1]. Figure 1 schematically shows the spin coating method and the bar coating method. The mechanism of the molecular ordering by the bar coating method is due to the gradient of shear force. When the organic polymers are coated along one direction, the gradient of the flow velocity near the PEDOT:PSS layers induced a viscous torque on the molecules. This causes the molecular alignment. The correlation between the molecular ordering and device performance is verified by the various analyses such as complex dielectric anisotropy and molecular crystallinity. The electro-optical characteristics such as luminous efficiency, power efficiency and external quantum efficiency of the OLED device were quantitatively compared.



(a) (b) (c)

Figure 1. Two kinds of coating methods for EML: (a) the spin coating method, (b) the bar coating method and (c) mechanism of molecular alignment by the viscous torque.

Acknowledgement
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* Author for Correspondence: cgjhun@hoseo.edu

Structural Control of Nucleobase Star Mesogens – Switching Bicontinuous Cubic Networks to Hexagonal Columnar Phases

Katja Noll[1], Matthias Lehmann[1]*

[1]Institute of Organic Chemistry, University of Würzburg, Würzburg 97074, Germany

Implementing the nucleobase thymine by spacers of varying lengths in the cavities of a hexasubstituted C_3-symmetric star-shaped molecule **1** (Figure 1) leads to the formation of an unusual bicontinuous cubic gyroid phase. In prior works, the cavities of such derivatives, consisting of a benzene core and oligo(phenylenevinylene) arms [1], have been filled either with aromatic acids as real guests via a single hydrogen bond or as pseudo guest bound through an ester link, as well as with Blatter radicals and peptides [2,3]. Thymine can enforce the supramolecular guest binding by a hydrogen bond array to form supermesogens with complementary bases. This will allow fine-tuning of the liquid-crystalline structure and reversible implementation of various functional building blocks.

The cubic phase of the neat molecule **1** is stable over a large temperature range from room temperature to 134-183 °C. The phase transitions temperatures to the columnar assemblies depend on the spacer length *n*. Variable temperature FT-IR studies show that hydrogen bonding of thymine is temperature- but not phase-dependent. Hence, the driving force for this exceptional structure formed by disc-like mesogens is solely the ratio of aromatic and aliphatic volume fractions of the molecular building blocks. As expected, NMR-dilution and -titration experiments reveal that in solution, the host molecules **1** display weak self-association and considerably stronger interactions with derivates of the complementary base adenine. Therefore, the Cub$_v$ phase can be switched to the Col$_h$ phase by incorporating adenine guests **2**.

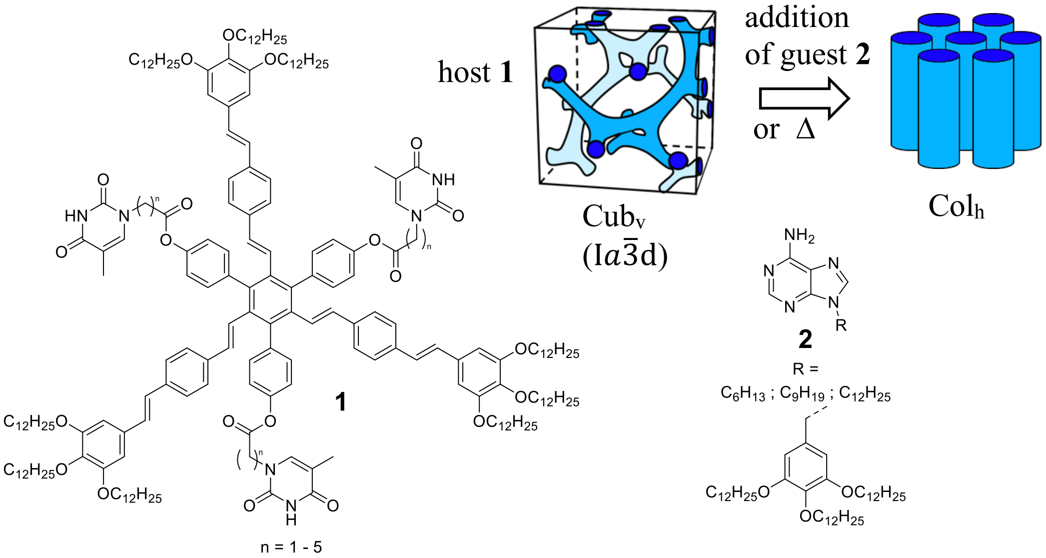

Figure 1. Star mesogens with attached thymine moieties and functionalized adenine guests.

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* Author for Correspondence: matthias.lehmann@uni-wuerzburg.de

Phase behavior, order and electro-optical properties of liquid crystals / quantum dots soft-nanocomposites

Stephanos Basim Atata, Ioannis Lelidis*

Physics Department, National and Kapodistrian University of Athens, Panepistimiopolis, GR-15784 Zografos, Greece

We investigated the effect of quantum dots on the orientational order, phase behavior and electrooptical properties of liquid crystals by means of polarized optical microscopy. In particular, nanocomposites of the 4-cyano-4'-octylbiphenyl liquid crystal with core-shell CdSe/ZnS quantum dots of two sizes were prepared [1]. The phase diagrams of the nanocomposites as function of the quantum dots' concentration and size were constructed. A large drop of the clearing temperature was measured along with a narrowing of the nematic phase temperature window. Microphase separation effects and formation of networks composed by nanoparticles appear above a critical concentration range [1,2]. The Freedericksz transition threshold and the switch-on and switch-off times were measured as a function of the quantum dots' concentration and size. The influence of nanoparticles on the pretilt angle in planar cell geometry and anchoring energy were investigated. The impact of the nanoparticles on the orientational order parameters P_2 and P_4 was investigated [1,3].

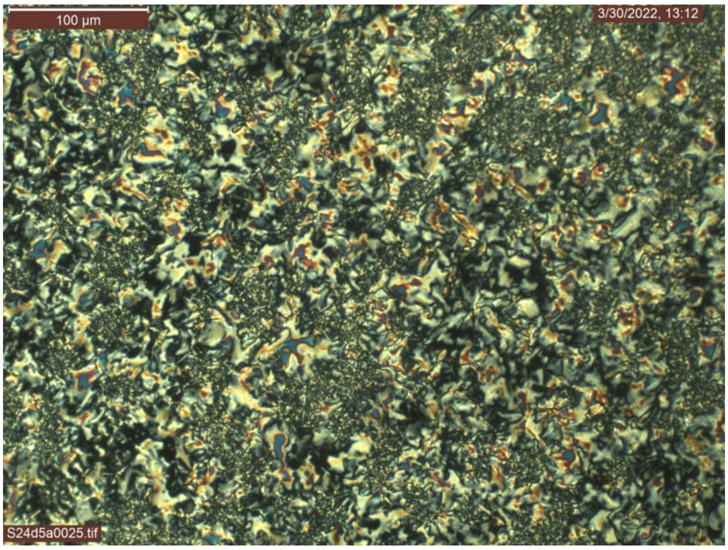

Figure 1. Microstructure of a 8CB-CdSe/ZnS nanocomposite at 0.4% w/w in nanoparticles. The nematic director is heavily stressed because of the presence of nanoparticles. Polarizing microscopy, crossed polarizers.

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* Author for Correspondence: ilelidis@phys.uoa.gr

Optically Coding in Cholesteric Liquid Crystals for a Data-hidden-LCD

Xiang Zhang, Yubo Wang, Shihao Sun, Yongfang Zhang, and Yang Liu*

College of Information Science and Technology, Donghua University, 2999 North Renmin Road, Songjiang District, Shanghai 201-620, China

Cholesteric liquid crystals (CLCs) with tunable Bragg reflection under multiple stimuli are an active area of interest for filters, lasers, displays, sensors, etc., and programmably manipulate the reflection of CLCs has emerged as an extremely essential issue. Evidence suggests that optically driven CLCs facilitating localized reflection have spatial advantages for remote and local control. In this research, the house-made transparent cell with a cell gap of 10 µm was made using one glass slide that coated with commercial polyimide and the other one coated by SD1 photo-responsive molecules, and filled with CLCs made from E7 nematic LCs and 1.0% S811 doping in the pitch of 10 µm. The LCs on SD1 molecules coated slide thereafter were in-plane switched clock-wisely by means of linear polarized blue laser (λ=405nm) irradiation, and thus elongate the pitch and tune reflection of CLCs. As the reflection of incident light has an extremely large wavelength ($\sim 14\times10^3$ nm) and is hard to be detected, the structure change induced optical performance in CLCs by in-plane switch of near-slide LCs was identified by a polarized optical microscopy (POM) under the transmission mode. As shown in Fig. 1, the cell inserted with CLCs was saw in purple initially, when the near-slide LCs were clock-wisely switched by π/4, 5π/12, 7π/12, 2π/3 and 5π/6, respectively, the cell turned to indigo, green, yellow, orange and pink accordingly. Alternatively, the induced pink cells can be counter-tuned to their initial purple by anti-clockwise laser irradiation. This observation suggests that the switching of near-slip LCs is sufficient for optically encoding in CLCs and could have significant applications in displays, especially in a data-hidden mode.

Figure 1. POM images of encoded CLCs with a linear polarized blue laser (λ=405nm).

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* Author for Correspondence: liuyang@dhu.edu.cn

Measurement of Spontaneous Polarisation in Ferroelectric Nematic Liquid Crystals

Diana Nikolova[1*], Peter J. Tipping[1], Richard Mandle[1,2], and Helen F. Gleeson[1]

[1]School of Physics and Astronomy, University of Leeds, Leeds, UK
[2] School of Chemistry, University of Leeds, Leeds, UK

First hypothesized in 1916, the ferroelectric nematic (N_f) phase was experimentally found in 2017 in two liquid crystals: DIO, synthesized by Nishikawa et al. [1], and RM734, synthesized by Mandle et al. [2,3] Values for spontaneous polarization for both DIO and RM734 have been previously reported [1,4] as being comparable to that of ferroelectric ceramics, which has generated great interest in utilizing them for various commercial applications. However, some difficulties exist that limit their applicability – most notably their monotropic nature and the high temperature threshold above which the N_f is observable. Hence, a material which overcomes these difficulties is desirable, particularly for commercial applications. Furthermore, the value of spontaneous polarization in N_f materials has typically been studied using the current-reversal technique in devices with cell gaps on the order of 5-10μm. [1, 4-6] Some applications, however, may demand a larger active mass of liquid crystal, thus prompting investigation into the use of thicker cells, as well as cells with larger active areas.

In this work, a mixture which exhibits an enantiotropic ferroelectric nematic phase at room temperature is introduced, and its spontaneous polarization is measured and reported using different cell geometries.

Acknowledgements: D.N., P. J. T., R. J. M., and H. F. G. acknowledge funding from EPSRC and Merck Electronics KGaA. The authors also acknowledge the supply of materials from Merck Electronics KGaA.

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* Author for Correspondence: py18dn@leeds.ac.uk

Reaction-diffusion origin of spatio-temporal dynamics of localized elastic excitations in photoactive chiral nematics

Tetiana Orlova[1,2*], Igor S. Lobanov[3], Ivan M. Tambovtsev[3], Federico Lancia[4], Supitchaya Iamsaard[4], Nathalie Katsonis[4], Alexei D. Kiselev[5], Valery M. Uzdin[3], and Etienne Brasselet[2]

[1] Infochemistry Scientific Center, ITMO University, Saint-Petersburg 197101, Russia
[2] Univ. Bordeaux, CNRS, Laboratoire Ondes et Matière d'Aquitaine, F-33400 Talence, France
[3] The Faculty of Physics, ITMO University, Saint-Petersburg 197101, Russia
[4] Stratingh Institute for Chemistry, University of Groningen, Nijenborgh 7, Groningen, The Netherlands
[5] Laboratory of Quantum Processes and Measurements, ITMO University, Saint-Petersburg 197101, Russia

A rich variety of localized elastic structures is known to exist in frustrated thin films of chiral nematics, such as skyrmions, torons and hopfions [1]. All these structures consist of spatially inhomogeneous distributions of the liquid crystal orientation, which are classified according to their singular and/or nonsingular topological features. In particular, the sensitivity of liquid crystals makes such structures attractive for developing novel optical structured materials whose foreseen application potential remains to be explored. These elastic quasiparticles can be created on-demand, for instance by local laser irradiation of initially undistorted chiral nematic film or randomly, for instance by thermal or electrical quenching of the whole sample, while the exact nature of the generated quasiparticles usually depends on the actual experimental conditions.

Recently it was shown that light-responsive chiral nematics obtained by doping a passive chiral nematic with photosensitive molecular motors can exhibit stationary revolving structures [2] triggered from steady static elastic excitations under nW power level [3]. Although diffusion processes have been highlighted to play a role [2], such spatio-temporal dynamics is not yet understood to date. Here we present a reaction-diffusion model that combines photochemical reaction, diffusion of ground state and excited species, and elastic distortions. This allows not only the quantitative description of all previously reported experimental observations, but also the prediction of nontrivial behaviors that have been all validated experimentally. This opens up for the quantitative exploration of out-of-equilibrium topological matter.

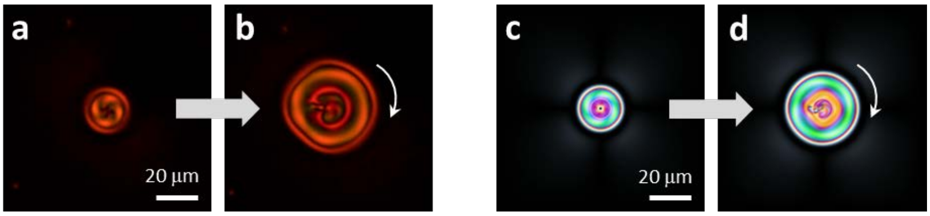

Figure 1. Cross-polarized optical images of the experimentally observed (a,b) and numerically simulated (c,d) transition from a steady static structure (a,c) to a revolving pattern (b,d).

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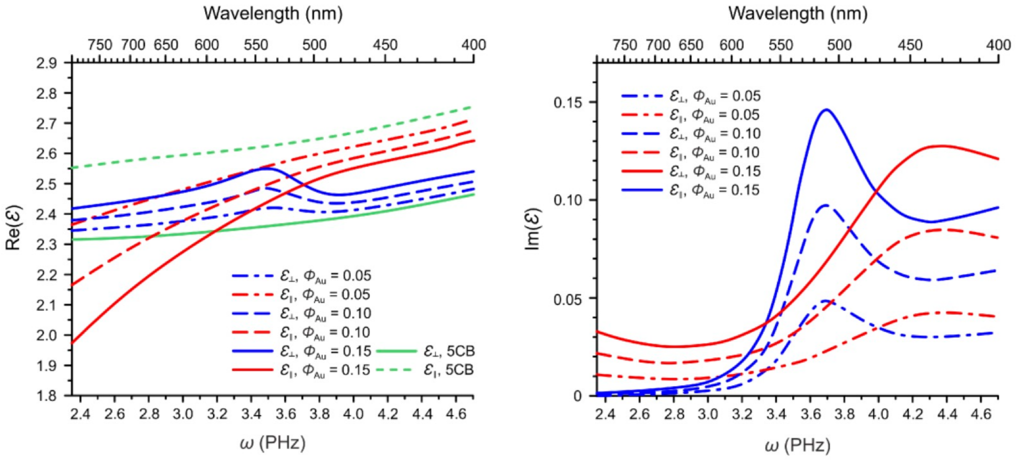
[*] Author for Correspondence: torlova@itmo.ru

Effect of Anisotropic Nanoparticles on the Dielectric Susceptibility of Nematic Nano-Composites: A Molecular Theory

M.A.Osipov*[a], A.S.Merekalov[b], A.A.Ezhov[c]

[a] *Department of Mathematics and Statistics, University of Strathclyde, Glasgow, UK*
[b] *Topchiev Institute of Petrochemical Synthesis, Russian Academy of Sciences, Moscow, Russia*
c Faculty of Physics, Lomonosov Moscow State University, Moscow, Russia
*m.osipov@strath.ac.uk

The effect of rod-like nanoparticles on the high-frequency dielectric susceptibility of the nematic nano-composites has been investigated in the framework of a molecular theory. Analytical expressions for the components of the effective polarizability of a rod-like nanoparticle in the nematic host have been obtained and used in the calculations of the dielectric susceptibility of the composites as functions of the nanoparticle volume fraction [1]. Numerical calculations of the susceptibility have been undertaken using the nematic liquid crystal *5CB* as a host doped with either gold or silver particles for different values of the concentration of nanoparticles. It has been shown that the rod-like nanoparticles have a much stronger effect on the components of the dielectric susceptibility of the nano-composites in comparison with spherical nano-particles [2] including, in particular, the one with gold nanoparticles in the vicinity of the plasmon resonance. The main conclusion is that at sufficiently large concentration of nanoparticles, the anisotropy of the dielectric susceptibility of the nano-composites may even change the sign with an increasing concentration which may be important for various applications.



(a) (b)

Figure 1. Real (**a**) and imaginary (**b**) parts of the transverse and longitudinal components of the high-frequency dielectric susceptibility of the 5CB nematic nano-composites for different values of the volume fractions of AuNPs.

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Liquid crystal tunable microcavities for generation of strong light - matter coupling

Przemysław Morawiak[1], Rafał Maur[1], Eva Oton[1], Mateusz Muszyński[2], Jacek Szczytko[2], Przemysław Kula[1] and Wiktor Piecek[1]

[1]Faculty of Advanced Technologies and Chemistry, Military University of Technology,
00-908 Warszawa, Poland
[2] Faculty of Physics, University of Warsaw, Warszawa, Poland

Liquid crystalline structures (LCs) are capable to modulate the parameters of travelling light due to the intrinsic anisotropy of the dielectric permittivity tensor as well as due to spatial modulation of an effective refractive index proper to a particular structure. Moreover, LCs are a perfect platform for manipulating polarization states of light in confined geometries. This issue is essentially important in emerging optical technologies. Here we focus on optical microresonators made of DBR mirrors of a high Q-factors (Fig.1). Such resonators are promising as platforms for testing laser sources, active filters and all-optical switches. Using LCs as a tunable medium a spatial manipulation of phase shift and polarization states of light is possible to induce and control resonances in optical microcavities (MCs). .

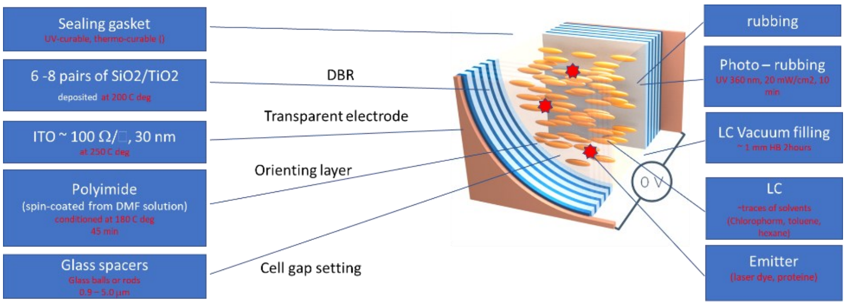

Figure 1. Scheme of an example of liquid crystal tunable microcavity used for induction of strong light matter coupling and lasing.

Fine-tuning of light confined in MCs allows for the induction of strong light-matter coupling [1, 2]. When emitting materials like dyes and polymers are present in LC-tuned MC the strong light-matter coupling was observed and studied [3]. Here we report peculiarities of LC-driven MC design and fabrication as well as an influence of the LC materials and structures on MC parameters and strong coupling effects observed.

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* Author for Correspondence: wiktor.piecek@wat.edu.pl

Oxazoline derivatives exhibiting chiral liquid crystalline mesophases

Natalia Podoliak[1*], Martin Cigl[1], Karel Pomeisl[1], Petra Vaňkátová[1], Věra Hamplová[1], Vladimíra Novotná[1], and Damian Pociecha[2]

[1] Institute of Physics of the Czech Academy of Sciences, Na Slovance 1999/2, 18200, Prague, Czech Republic
[2] Chemistry Department, Warsaw University, Al. Zwirki i Wigury Warsaw, Poland

We designed new chiral mesogens **OXm/n** containing a chiral oxazoline fragment derived from the natural L-serine amino acid. Our effort was concentrated on the evaluation of the synthetic accessibility of these new compounds including the optical purity of the materials using chiral HPLC. We established the mesomorphic properties and confirmed the phase identification by x-ray scattering studies. We found that the studied materials exhibited various smectic mesophases depending on the length of the terminal alkyl chains. **OXm/n** derivatives with conformationally rigid oxazoline chiral moiety were compared with the structurally almost identical smectogens **ZLm/n** having a flexible (S)-lactate chiral unit [1] with the aim to investigate the effect of the rigidisation of the chiral unit on the mesomorphic properties.

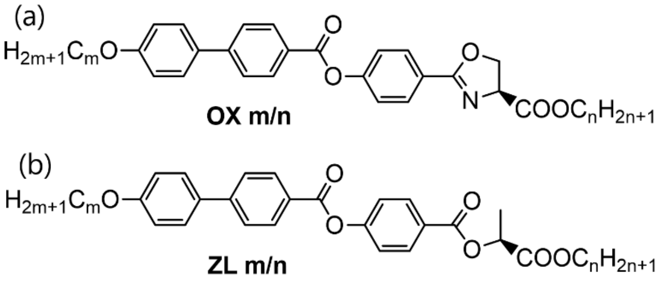

Figure 1. Chemical formula of (a) studied oxazoline compounds OXm/n and, for comparison, (b) the previously synthesised lactic derivatives ZLm/n.

The synthesised materials **OXm/n** possess various lamellar phases depending on the lengths of the terminal chains, including ferroelectric SmC* phase with a tilt angle up to 23° and a spontaneous polarisation reaching 60 nC/cm^2. Despite our expectation to develop materials of strong chirality, only TGBA phase, which is not present in the analogous **ZLm/n** series, can suggest stronger chirality of oxazoline derivatives. The comparison of **OXm/n** with the analogous materials **ZLm/n** revealed the effects of molecular rigidisation. Generally, it leads to higher melting points and reduced mesophase temperature intervals and, perhaps, the dominance of the tilted SmC* phase on the expense of non-tilted mesophases. The reduced mesomorphism is, most probably, caused by highly bent geometry of the oxazoline materials.

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* Author for Correspondence: podoliak@fzu.cz

Mesomorphic properties of enantiomers and racemates of cinnamic acid derivatives

Natalia Podoliak[1*], Terézia Jurkovičová[1], Petra Vaňkátová[1,2], Martin Cigl[1],
Vladimíra Novotná[1] and Věra Hamplová[1]

[1]Institute of Physics of the Czech Academy of Sciences, Na Slovance 1999/2, 18200, Prague, Czech Republic
[2] Department of Analytical Chemistry, Faculty of Science, Charles University, Hlavova 2030/8, 128 43 Praha 2, Czech Republic

Liquid crystalline (LC) materials reveal variety of phases and structures depending on the properties of the constituting molecules. Molecular chirality influences the mesomorphic behaviour as well as physical properties of the observed mesophases. Additional properties, such as photosensitivity, can be brought to LC materials by the molecular modification to enhance the multifunctionality of the studied system. Contrary to azo-based photosensitive LC materials, which have been frequently studied, only limited LC compounds have been based on cinnamic acids.

In this contribution, we present new cinnamic derivatives **nSCHL** with a lactate in the chiral chain. Two new chiral liquid crystal materials **nSCHL**, **n** = 6; 10, derived from cinnamic acid, were synthesised in (*R*) and (*S*) enantiomer forms. The molecular structure of the studied compounds is shown in Figure 1. The final products were analysed by HPLC in a reversed mode on pentafluorophenyl stationary phase and their chemical purity was determined. The effect of photoisomerisation on the enantioselective HPLC separation was studied before and after UV irradiation.

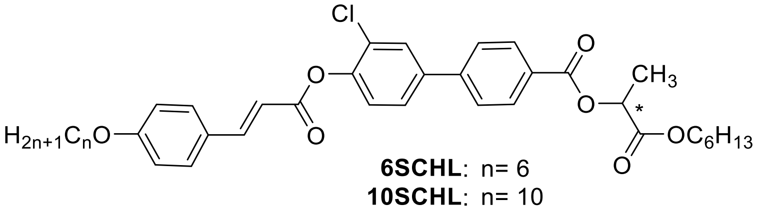

Figure 1. Molecular structure of the studied cinnamic derivatives

We studied the mesomorphic properties of the synthesised enantiomers as well as their racemic mixtures. The phases were confirmed by the polarising optical microscopy studies. The precise transition temperatures were obtained from the differential scanning calorimetry. Additionally, the birefringence was measured for the racemate materials. For the shorter homologue, **6SCHL**, cholesteric phase was found for chiral enantiomers and, correspondingly, nematic phase was observed for the racemate. For the longer **10SCHL** (*R*) and (*S*) enantiomers, TGBA and TGBC phases were observed besides the cholesteric phase on cooling from the isotropic phase. For the corresponding racemate, subsequently, SmA and SmC phases appeared below the nematic one.

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* Author for Correspondence: podoliak@fzu.cz

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Electronic drivers design for liquid crystal phase devices

X. Quintana, I.H. Fumero, M.A. Geday, P. de la Rosa, J. Pereiro-García, M. Caño-García

CEMDATIC, ETSI Telecomunicación, Universidad Politécnica de Madrid, Spain
* Corresponding author: x.quintana@upm.es

The electrical excitation of multi-electrode phase devices requires the application of a large number of different simultaneous programmable voltages. No generic excitation circuits can cope with these driving schemes; in fact, the circuits commonly used in LCD drivers employ significantly lower voltages than those required by many manufactured phase devices. Therefore, ad hoc customized circuits are often required.

The specifications usually involve high switching voltages (tens of volts), fast response and flexible programming. This implies the use of microprocessors (or FPGAs) and the development of specific circuitry. In some cases, the use of *dual frequency* liquid crystals also implies the use of at least two switching frequencies, one around 1 kHz and the other around 100 kHz, which complicates the drivers' design.

Three electronic drivers with different addressing schemes have been designed, fabricated and tested in this work. The first driver is based on analog switches [ADG5413BRUZ] and LED drivers, and the other two drivers are based on two D/A converters [AD5360EBZ and BAC81416]. The first design has a high number of components that increases its complexity. The other two are simpler from the implementation point of view, although somewhat more complicated to program.

In the case of dual frequency liquid crystals and high voltages (used for example in microwave reflectarrays) a scheme of D/A converters followed by an amplification circuit has to be used, since the slew rate of D/A converters (due to the internal conversion procedure) makes it impossible to reach high voltages (tens of volts) at frequencies in the 100kHz range. However, D/A converters work properly at these frequencies tackling with low voltages (1-2 V) that can be eventually amplified.

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Space-filling in polar phases of star-shaped molecules with C_{60} fullerenes by covalent attachment

Lisa Reber[1], Maximilian Baumann[1], Matthias Lehmann[1*], Alexey Eremin[2], Ahmad Murad[2], and Dharmendra Pratap Singh[3]

[1] Institute of Organic Chemistry, University of Würzburg, Würzburg 97074, Germany
[2] Institute of Physics, University of Magdeburg, Magdeburg 39016, Germany
[3] Unité de Dynamique et Structure des Matériaux Moléculaires, ULCO, Calais 62228 cedex, France

Ferroelectric phases recently step in the focus of LC research, since they promote a bulk anomalous photovoltaic effect [1,2]. Besides, calamitic oligothiophenes also bowl-shaped subphthalocyanines were shown to be effective.

Our group recently demonstrated a new click procedure, in which a mixture of zinc phthalocyanine star mesogens without and with fullerenes generated a unique donor-acceptor LC structure [3,4]. The high clearing temperature, however, prevented the alignment and hampered its photovoltaic performance. Noncentrosymmetric columnar assemblies of boron-subphthalocyanines were found to combine low clearing temperatures, ferroelectric phases and thus, alignability in electric fields [5]. The attachment of fullerenes C_{60} to the subphthalocyanines to realize the click procedure turned out to be very challenging.

Here, the preparation of the missing link, the fullerene C_{60} conjugates attached via flexible spacers, are highlighted and the structure-property relationships of the neat compounds and their mixtures are discussed.

SP1-3 **SPF**

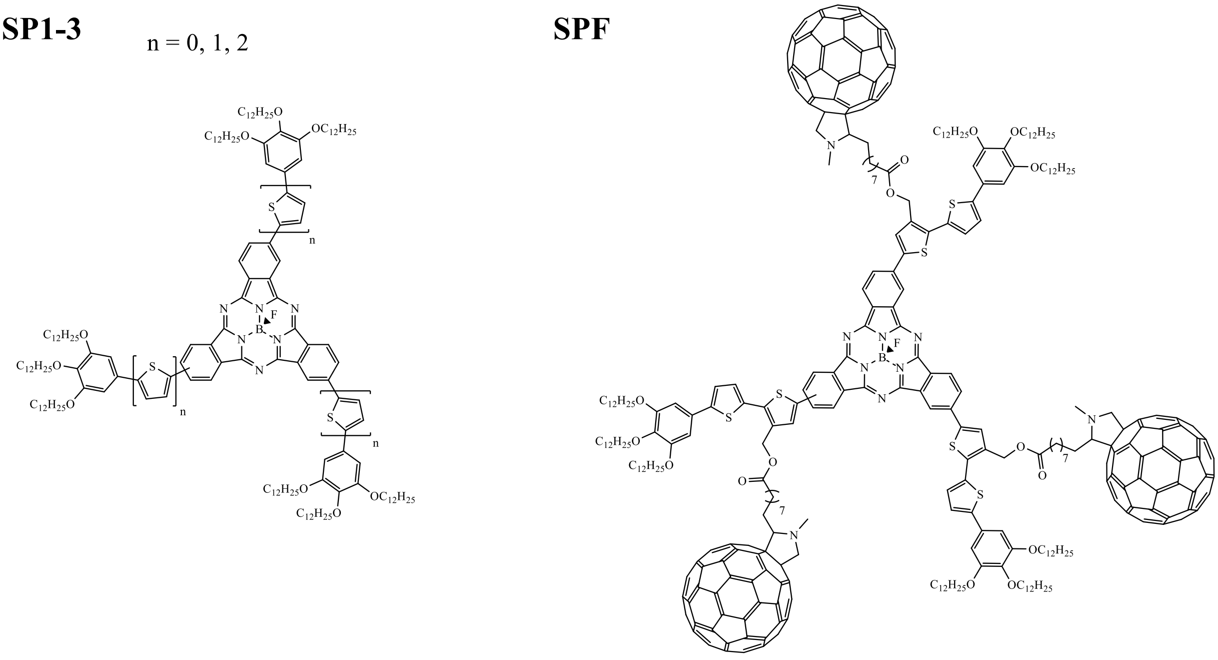

Figure 1. Structures of target molecules **SP1-3** and **SPF**.

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* Author for Correspondence: matthias.lehmann@uni-wuerzburg.de

Beyond 3D microfabrication in reactive mesogens

T. Ritacco[1,2], D.M. Aceti[3], A. Mazzulla[2], G. De Domenico[1], M. Giocondo[2], G. Cipparrone[1,2],
and P. Pagliusi[1,2],*

[1] Physics Department, University of Calabria, Rende (CS) Italy
[2] CNR-Nanotec, Institute of Nanotechnology, S.S Cosenza, Rende (CS), Italy
[3] Institute of Electronics, Bulgarian Academy of Sciences, Sofia, Bulgaria

Two-photon lithography (TPL) is an advanced technique that enables the precise fabrication of complex 3D structures at the nanoscale level. [1-3] By applying TPL to liquid crystalline photo-curable resins, also known as reactive mesogens (RMs), it is possible to create microbjects that exhibit the optical response of liquid crystals while maintaining the mechanical properties of polymers. [4-6]

Here we demonstrate how it is possible to take advantage of the various TPL parameters to conveniently adjust the intrinsic RMs properties (i.e. order, alignment, etc.), without the need of other external controls (i.e. temperature, voltage, etc.). In particular, we show that the birefringence and optical axis of a nematic RMs film could be locally preserved or deliberately altered, depending on the exposure geometrical and physical parameters (i.e., direction, spacing, speed, power of the scanning laser beam). Furthermore, we demonstrate that the photonic band gap of a photo-curable cholesteric RMs mixture [7-9] can finely tuned across the whole visible range, in a single-step fabrication session, by tuning the delivered energy dose. Examples of 4D microstructures are shown, which could pave the way for a new family of security devices. [10]

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* Author for Correspondence: pasquale.pagliusi@fis.unical.it

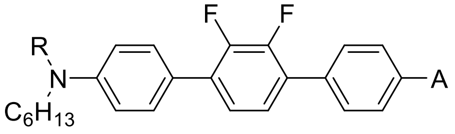
Synthesis and characterization of organic emitters for luminescent liquid crystalline materials

Natan Rychłowicz[1], Marcin Muszyński[2], Noureddine Bennis[1], Jacek Szczytko[2], Wiktor Piecek[1], and Przemysław Kula[1*]

[1]Faculty of Advanced Technologies and Chemistry, Military University of Technology, Warsaw, Poland
[2] Faculty of Physics, University of Warsaw, Warsaw, Poland

Liquid crystalline materials, doped with luminescent particles (organic emitters, nanoparticles) are widely studied because of many potential applications of such composites in optoelectronic devices[1]. Organic push-pull dyes with rod-like shape possess a transition moment vector oriented along the long axis of the molecule. Doping such dye to an LC mixture allows one to obtain a material with a self-orienting and switchable absorption parallel to a director. The tunability of such material can work in two ways: absorption/emission polarization direction or emission intensity, and can be utilized in devices such as switchable optical filters and polarizers[2,3].

In this work we present the synthesis and properties of a class of push-pull emitters, possessing N,N-dialkylamine as an electron-donating group and a variety of electron-withdrawing groups. We characterized mesomorphic properties and solubility in different LC mixtures, as well as spectral properties. Theoretical calculations were performed. We designed LC mixtures containing synthesized emitters and measured the polarization state of emitted light, as well as emission intensity for different values of applied voltage. Our emitters have high values of quantum yield and high solubility in LC mixtures. Emitters doped to LC mixtures allow to obtain materials with high dichroic ratio and switchable emission intensity.



R = C_6H_{13}, CH_3

A - electron-withdrawing group

Figure 1. General structure of synthesized dyes

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* Author for Correspondence: przemyslaw.kula@wat.edu.pl

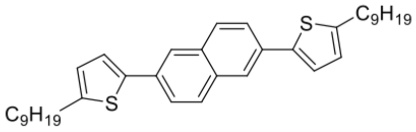
Liquid crystalline composites toward a novel tuning technique of semiconducting polymers

Yo Shimizu[1*], Koki Kawano[1,2], Masato Yamamoto[2], Kingo Uchida[2], Noboru Ohta[3], Tsuyoshi Kawai[1], Akihiko Fujii[4], and Masanori Ozaki[4]

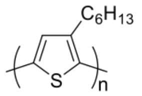
[1] Graduate School of Science and Technology, Nara Institute of Science and Technology (NAIST), Ikoma, Nara, Japan
[2] Department of Materials Chemistry, Faculty of Science and Technology, Ryukoku University, Otsu, Shiga, Japan
[3] Japan Synchrotron Radiation Research Institute (JASRI), Sayo, Hyogo, Japan

[4] Graduate School of Engineering, Osaka University, Suita, Osaka, Japan

Strong self-assembling nature of liquid crystals is fascinating in terms of thin film fabrication, if it is used as solid state, to withdraw the potential performance as semiconducting properties of organic molecules such as carrier mobility. On the other hand, miscibility and phase separation are also interesting characters of liquid crystals, if spontaneous formation of nano-scale structure on these characters can improve the system performance for charge/exiton migrations.



2,6-di(5'-n-alkyl-2'-thienyl)naphthalene (9TNAT9)



Regioregular poly (3-hexyl) thiophene (P3HT)

In this communication, liquid crystalline composites as semiconducting materials are studied as a trial to give a new methodology for control of electronic properties in molecular materials and the results are shown for the combination of low-molecular weight liquid crystalline semiconductors (TNAT : dithienylnaphthalene derivatives, the nonyl homologue was used [1]) and polymer liquid crystalline semiconductor (P3HT). It was found that phase separation takes place in the wider region of component ratio, though P3HT is well-known as liquid crystalline polymer of which melting point is >240 °C. The drift mobility measurements by time-of-flight technique reveal that the mixing of a mesogenic TNAT with P3HT leads to the enhancement of carrier transport efficiency, even in the small component ratio of TNAT (ca. 23 mole% as to the monomer unit of P3HT) and the comparable level of mobility is attained to the case of well-aligned P3HT (~ 10^{-1} cm^2 / Vs). The structure modification of this binary system by doping of TNAT molecules is investigated with XRD measurements.

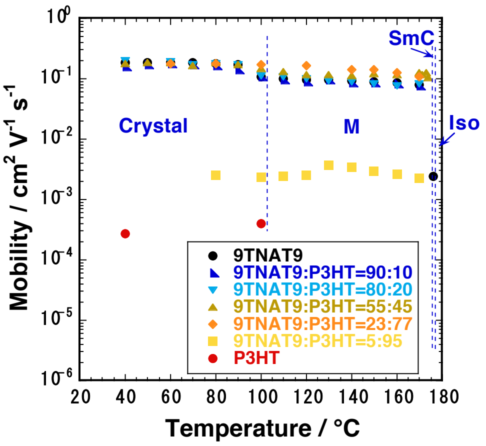


Fig.1 Temperature dependence of hole mobility for the mixtures of P3HT and 9TNAT9.

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* Author for Correspondence: yo-shimizu@ms.naist.jp

Chiral chromonic liquid crystals microspheres embedded in flexible films

Lorenza Spina[1,2,*], Federica Ciuchi[1], Caterina Maria Tone[1,2], Riccardo C. Barberi[1] and Maria Penelope De Santo[1]

[1]Physics Department, University of Calabria, Rende 87036, CS, Italy
[2] CNR-Nanotec, c/o University of Calabria, Rende 87036, CS, Italy

Being able to obtain well defined optical textures is the first crucial step towards the use of chromonic liquid crystals confined in microspheres for practical applications [1]. It is well known that Frank-Pryce textures, similar to the ones observed in thermotropic liquid crystals microspheres, can be obtained doping a chromonic with an high twisting power amino acid and creating an emulsion [2].

Here we demonstrate that it is possible to preserve this microspheres texture when they are embedded in a flexible film. This was obtained preparing an emulsion using PDMS mixed with its hardener as dispersing fluid. This represents a first step for the creation of chromonics based biocompatible and eco-friendly flexible films. Due to the temperature sensitivity of the texture, at present, applications in the food cold chain tracing and sensor technology are envisaged.

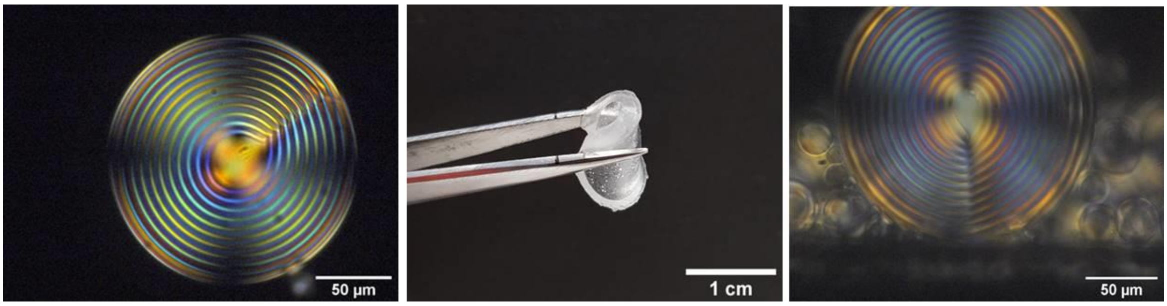

Figure 1. Chiral chromonic microsphere in an emulsion (left), flexible PDMS film containing chromomics microspheres (centre), microsphere embedded in the PDMS film (right).

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* Author for Correspondence: loryspina@libero.it

Water droplet impact on liquid crystal interfaces

Rok Štanc[1], Yang Xu[2], Robert Dupont[2], Xiaoguang Wang[2], Simon Čopar[3] & Uroš Tkalec[1,4,5*]

[1]Faculty of Medicine, University of Ljubljana, Ljubljana, Slovenia
[2]Department of Chemical and Biomolecular Engineering, The Ohio State University, Columbus, OH, USA
[3]Faculty of Mathematics and Physics, University of Ljubljana, Ljubljana, Slovenia
[4]Faculty of Natural Sciences and Mathematics, University of Maribor, Maribor, Slovenia
[5]Department of Condensed Matter Physics, Jožef Stefan Institute, Ljubljana, Slovenia

The dynamic interaction of droplets with slippery surfaces involves intriguing fluid mechanics that is essential to many applications, including bio-printing, spraying, and coating technologies, self-cleaning, anti-icing, bio-fouling, and smart biomaterials [1]. We investigate the effect of thermotropic liquid crystal (LC) mesophase on water drop impact behaviors (bouncing, spreading, retraction, wetting) on LC-infused porous surfaces [2]. We use high-speed camera recordings to study the role of surface tension, dynamic viscosity, elasticity, and molecular orders in smectic, nematic, and isotropic LC mesophases on the drop impact phenomena. The rebound regimes are characterized as a function of the Weber number, retraction velocity, contact angle hysteresis, and morphological changes. We primarily focus on the deposition regime where the surface chemistry, roughness, and wettability of the LC mesophase play an important role in the early stages of the impact dynamics. Our research is based on water droplets with volumes of approximately 5 μl. To examine the impact of droplet volume on dynamics, we compare the retraction rates of both smaller and larger volume droplets. Additionally, we investigate the effect of surface tension on dynamics by creating a water-surfactant solution and comparing the impact dynamics of these droplets as well. Finally, we hypothesize that some of the exerted experiments could lead to drop impact-activated release of micrometer-sized LC droplets encapsulated within the water droplet, which could be interesting for many applications. One of the purposes of our research is to investigate and describe when and why this phenomenon occurs, but in general, we would like to understand the dynamics of water droplet impact on soft substrates, especially on the LC interface in different mesophases.

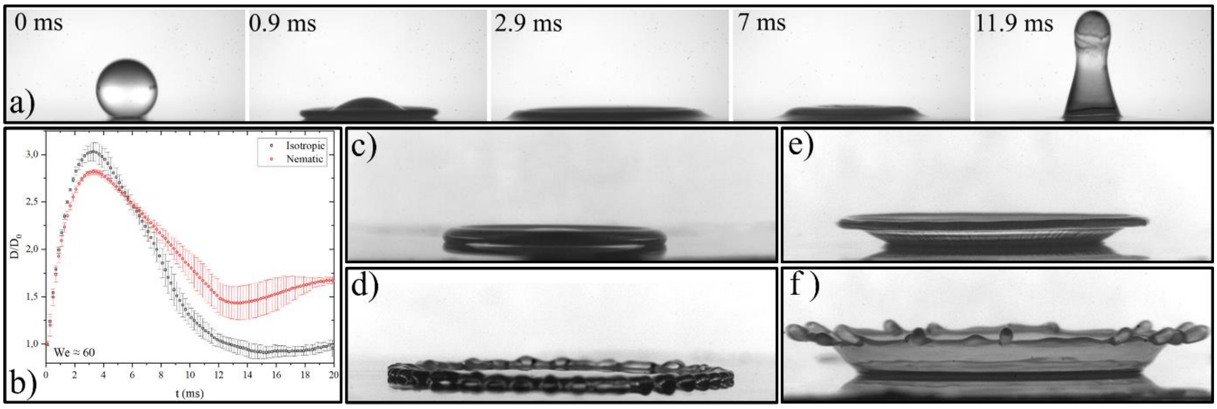

Figure 1. a) Image sequence of water droplet impact on LC interface in isotropic phase (We≈75). b) Droplet spreading and retraction dynamics after impact on isotropic and nematic phase. c-f) Phenomenon after impact: c) deposition (flat rim), d) deposition (wavy rim) e) deposition (crown), f) receding breakup (wavy crown).

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* Author for Correspondence: uros.tkalec@mf.uni-lj.si

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The influence of binary monomer mixtures on the polymer stabilisation of helicoidal structure of the antiferroelectric phase

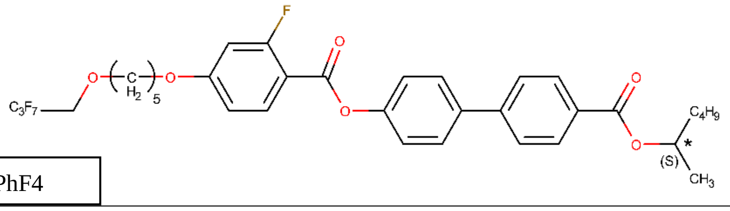
Michał Szarek, Aleksandra Kamer, Michał Czerwiński, Przemysław Kula

Institute of Chemistry, Military University of Technology, Warsaw, Poland

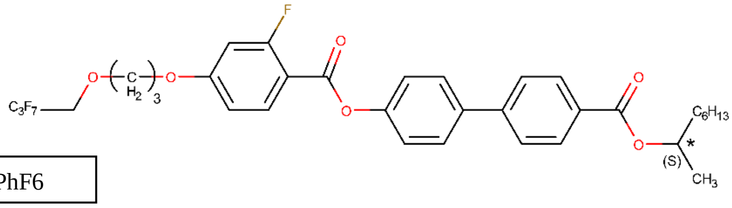
One significant issue in using antiferroelectric and ferroelectric liquid crystals (A)FLCs for new technologies based on deformed helix (DH) mode [1] is the large temperature dependence of the helical pitch (p). A potential solution to this problem is the use of a polymer network, which would stiffen the helicoidal structure of (A)FLC materials and mitigate the mentioned temperature-dependent issue. The helical pitch should remain constant over a wide temperature range in such polymer stabilised materials, making them an attractive option for technological applications, including, among others, tunable color filters and polarisers, devices for spectra information extraction, sensing systems for the study of: flow, pressure, gas and electric fields, and optical biopotential transducers. The polymer stabilization of the helicoidal structure of (A)FLCs is a relatively recent topic that has not been extensively covered in the literature [2,3,4]. Publications [2,3] contain a significant inaccuracy related to the monomers used, as their structure was incompatible with the components of the FLC mixture studied. Additionally, two research teams working on the same material used measurement cells with different thicknesses, resulting in vastly different results for polymer stabilization.

We focused primarily on the antiferroelectric phase in our work. The key difference from the studies mentioned in the publications [2,3,4] is our approach to the design, synthesis, and selection of suitable AFLCs and monomers. We ensured that the components were structurally compatible with each other. To achieve this, we used an equimolar liquid crystalline mixture of W-451 comprising two AFLCs with a rigid core of three aromatic rings, one partially fluorinated achiral terminal chain, and another chiral terminal chain (see Table 1).

Table 1. The composition of the liquid crystal mixture W-451



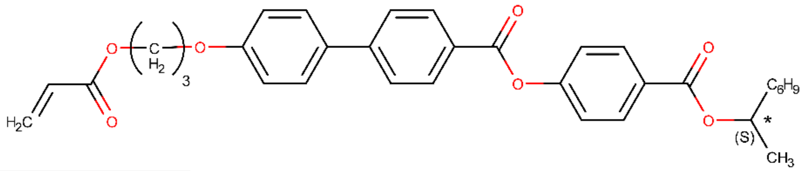
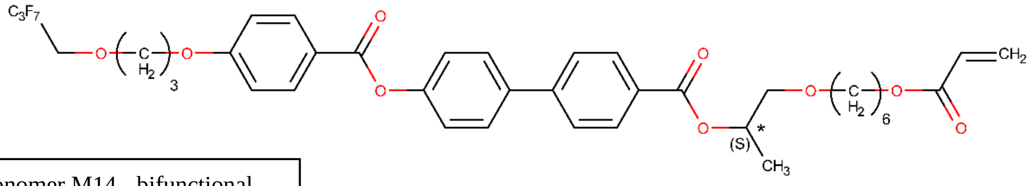
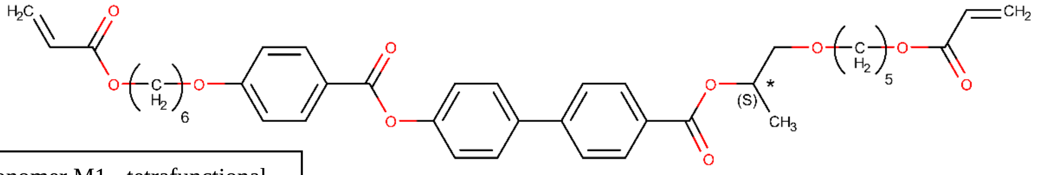
3F5HPhF4



3F3HPhF6

We also used binary mixtures of various monomers (see Table 2) as dopants together with minute amounts of photoinitiator, which accounted for 6.0% of the weight of the mixture tested. The mixtures prepared in this manner underwent photopolymerization with UV light at a power of 8.0mW/cm^2 and the appropriate temperature. The exposure time was set at 900s.

Table 2. Structural formulas of the monomers used for polymer stabilisation.

	Monomer M2 - bifunctional
	Monomer M14 - bifunctional
	Monomer M1 - tetrafunctional

The helicoidal structure was successfully stabilized by adding a mixture of tetrafunctional and bifunctional monomers to the W-451 mixture in a ratio of 3:1. When using a 1:1 ratio of the same monomers, the helix was also stabilized, but only at temperature where mixture shows long helical pitch and with bifunctional monomer that exhibit a reactive group in the achiral terminal chain (M2). In spectra showing the stabilisation of the structure, an interesting phenomenon is observed. One type of peak, which stacks one under the other for particular temperatures, is tentatively identified as peaks from the "primary" helix, indicating the polymerisation of the helix. Additional peaks are also observed, which shift towards longer wavelengths with decreasing temperature. These peaks are termed peaks originating from the "secondary" helix, indicating a lack of polymerisation of the helical structure. It is likely, in samples where the liquid crystalline material has been successfully polymerised, there are two distinct areas: a polymerised area with a fully stabilised "primary" helicoidal structure and an unpolymerised area with a "secondary" helical structure that is not stabilised by the polymer network but has a longer helical pitch than in the mixture before polymerisation.

Keywords: antiferroelectric liquid crystal (AFLC), helicoidal structure, polymer network, photopolymerisation, helix stabilization, helical pitch
Acknowledgment: This work was financed by Military University of Technology under research project UGB 22-801

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Dimeric liquid crystal nanocomposites functionalized by graphene oxide and amide graphene oxide

Boyko Katranchev[1*], Minko Petrov[1], Haritun Naradikian[1], Todor Vlakhov[1], and Marco Castriota[2]

[1]G. Nadjakov Institute of Solid State Physics, 72 Tzarigradsko chaussee blvd.,1784, Sofia, Bulgaria
[2] Physics Department, University of Calabria, Rende 87036, CS, Italy

Using the typical experimental methods, polarization microtexture analysis and differential scanning calorimetry (DSC), we have studied the effect of both nanoparticles (NPs) graphene oxide (GO) and amide graphene oxide (AmGO) respectively, on the thermal and structural properties of the hydrogen bonded in dimer liquid crystal (HBDLCs). We have used this graphene derivatives with chemical attachment of functional group to the graphene hexagons, to study the generation and development of smectic C_G phase in its bitilted configuration, manifested in two detached sub-structures denoted as C_{Gcl} (clinic) and C_{Gln} (leaning), in nanocomposites of HBDLCs with admixture of GO and AmGO.

For that purpose we explored nanocomposites built of HBDLCs, in particular the seventh homologue of 4-alkyloxybenzoic acid (7OBA) with GO and AmGO respectively, thus discovering a cascade of phase transitions between chiral, achiral and reentrant phases not typical for pristine 7OBA. We have selected 7OBA, among the homologues of the HBDLC, due to its thermal and chemical stability, as well as, due to its effectiveness in creating of nanocomposite with desire electrooptical properties, including both low electric field and fast electrical response. Besides, the used 7OBA/graphene derivatives nanocomposites, because of the effective functionalizing properties of GO and AmGO, one generates and develop the ferroelectric smectic C_G phase in its bi-tilted configuration. LC geometry determines C_G as an unique LC phase, developed due to a symmetry lowering in each distinct 7OBA molecule, caused by adopting the bent-dimer shape, thus depicting a double tilted structure with a global C1 symmetry.

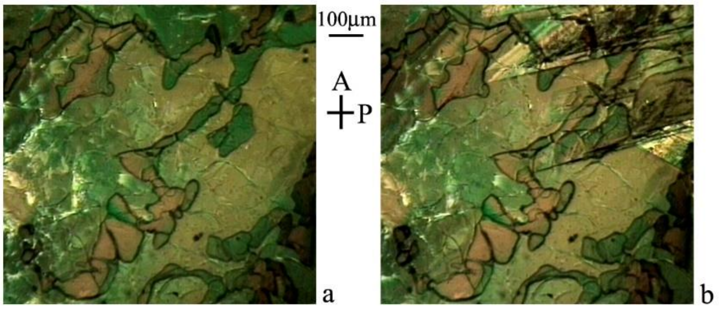

Figure 1. The a) clinic and b) leaning bitilted S_G textures.

Our DSC analysis indicated a novel effect concerning C_{Gcl} and C_{Gln} phase transition as such driven by van't Hoff enthalpy ΔH_{vH}.

The shape of the DSC peaks and their sharpness are the fundamental characteristics of the C_{Gcl} to C_{Gln} phase transition. They indicate the molecular conformation and correlation during the transition process. By the DSC thermogrames one can see that the peaks are asymmetric, indicating a noncompletely cooperative transition, between C_{Gcl} and C_{Gln} phases, thus involving a transient intermediate ordered structure. This state could be a result from the formation of 'islands', reflecting the disordered mobile areas within the C_{Gcl} phase. Such domains are generated by the lateral movement of the dimer molecules space frame. Furthermore, the C_{Gcl} and C_{Gln} phase transition is not fully cooperative, as it should be for a pure first-order phase transition where the DSC curve is expected to be symmetric, similar to a Gaussian one. Hence, the molecules aggregate in 'islands', thereby, presenting a transient intermediate structure, between C_{Gcl} and C_{Gln} phases, produced by the transitional constitutive structural units CU.

The asymmetric shape of the endothermic peaks in the thermograms suggests a fitting of the intermediate phase. As a result, it is assumed that the calorimetric enthalpy ΔH_{cal}, evaluated from the figures is rather a van't Hoff one, reporting the quantity of heat, that any CU units, developed in the intermediate temperature interval, must absorb in order for the phase transition to take place. Therefore, considering the calorimetric peak asymmetry, the results of the investigated DSC sample hint for partially a cooperative transition with two distinct enthalpies: the van't Hoff enthalpy ΔH_{vH} and the calorimetric enthalpy ΔH_{cal} a subject of the shape analysis of the calorimetric data allowing evaluation of the cooperativity factor from the ratio $\Delta H_{cal}/\Delta H_{vH}$, as well. We indicated that ΔH_{vH} must express the enthalpy changes associated with the disruption of a single CU within the LC matrix.

For the appearance of the C_G phase with its substructures in such nanocomposites, we propose an explanation based on the HB formation between 7OBA dimers in closed and open conformations and the graphene sheets, aided by the π–π interaction with graphene hexagons. We propose molecular and macroscopic models for the substructures C_{Gcl} and C_{Gln} and indicate their triclinic C_1 symmetry, characterized by a polar vector directed oblique to the layers, thus creating out of plane ferroelectric polarization. Such a configuration confirms that the bi-tilted C_G and its substructures are ferroelectric in the bulk similarly to solid ferroelectrics.

Due to these complex interactions the dimer molecule bends and undergoes different coupling combinations of the clinic and leaning degree of freedom of the doubly tilted molecular geometry in the C_G ordering. Such an energetic balance suggests a local and subsequently macroscopic symmetry decrease and adequate deformation of the nanocomposite structure leading to induction of both C_{Gcl} and C_{Gln} substructures. To more specific, the observed anisotropy and in-plane fluidity of C_G shows that no one of the principle axes of the second rank tensor, characterizing the orientational order, respectively the dielectric tensor, forms an angle of 0° or 90° with the smectic layer's planes.

We found that the electrooptical behaviour of the induced two substructures of bi-tilted ferroelectric smectic C_G phase in 7OBA/graphene materials to a great extent depend and can be controlled by the hydrogen bonding of the dimeric LC matrix with GO hydroxyl (carboxyl) groups, as well as with AmGO functionalized by amide $[CON(CH_3)_2]$ groups. It is worth to note that in the set of functionalizing groups, creating HBs, like hydroxyl and carboxyl attached to periphery of the GO sheet, that of the amide group attached to AmGO is dominating.

Finally, we state that as a result of these complex interactions the dimer molecule bends and undergoes different coupling combinations of the clinic and leaning degree of freedom exposed by the substructures C_{Gcl} and C_{Gln} with C_1 symmetry.

Acknowledgments: This work was supported by the National Science Fund of Bulgaria, the Ministry of Education and Science, contract No. KP-06-N58/6/2021, "Structural and functional investigations of liquid-crystal nanocomposites for applications in photonics, sensorics and biomedicine".

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* Author for Correspondence: boykopk@issp.bas.bg

Biaxial Self-Assembly with a Biaxial Nematogen – Optimization by Molecular Design

Pascal Weinberger[1], Nikolai Scheuring[1], Richard Mandle[2], Matthias Lehmann[1]*

[1]Institute of Organic Chemistry, University of Würzburg, Würzburg 97074, Germany
[2]School of Physics and Astronomy, University of Leeds, Leeds LS29JT, Great Britain

After the prediction of a biaxial nematic phase by Freiser in 1970 [1] two intense research periods aimed for the discovery of the real biaxial nematic phase for low molar mass thermotropic materials.[2] About a decade ago, it was concluded that finally no biaxial nematic phase had been confirmed and widely accepted.[2] We recently designed a family of roof-shaped molecules **1** (Figure 1) with a rectangular basal area. The experimental over-all aspect ratio L : B : W is 10.73 : 3.16 : 1.23 and is therefore close to the optimum molecular biaxiality according to Straley (10 : 3.16 : 1).[3,4] It contains a long conjugated molecular axis, which can be easily aligned by a magnetic field. The strong dipole along the minor axis responds to electric fields. Results of X-ray scattering and NMR relaxometry point to a biaxial self-assembly and show that at least biaxial aggregates of several hundreds of biaxial molecules exist.[3] For this reason, we synthesized a library of molecules based on the lead structure **1** and **2** (Figure 1).

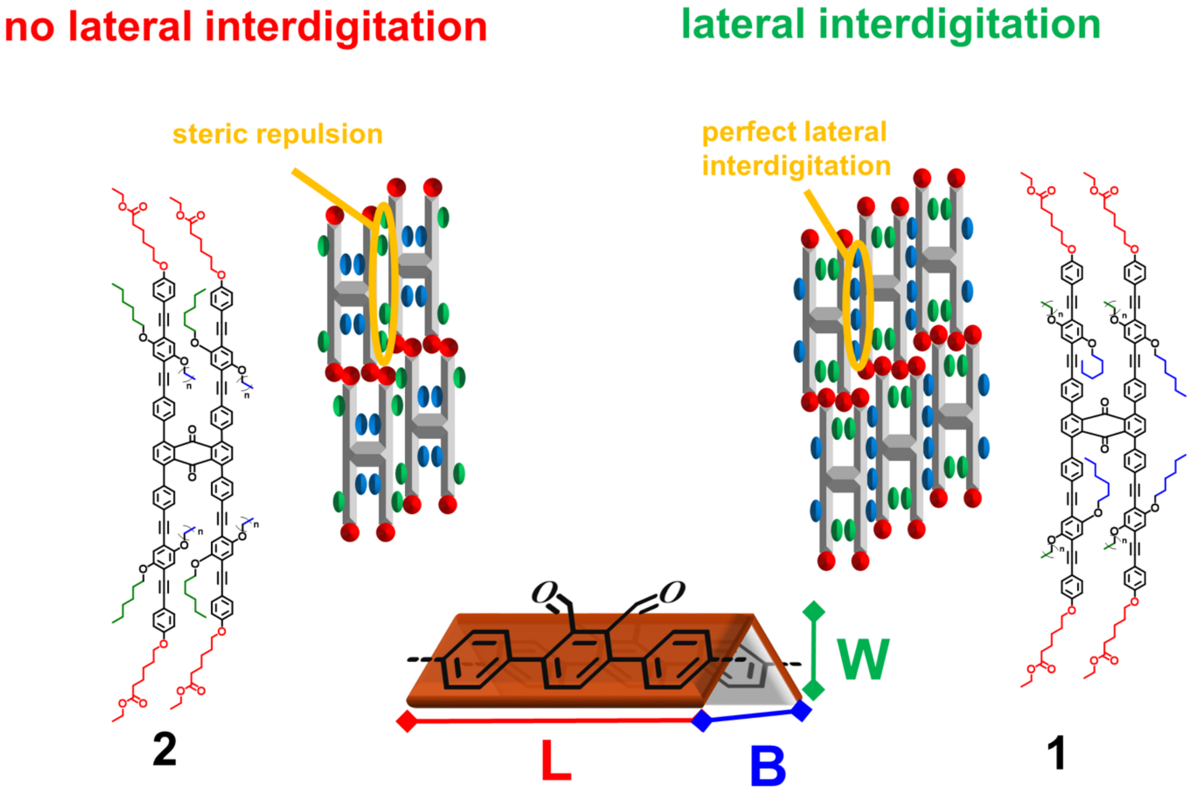

Figure 1. Biaxial, roof-shaped nematogens **1** and **2** with different substitution patterns.

Here we will highlight two types of molecules with a unique substitution pattern **1** and **2**. The results of X-ray scattering clearly show that nematogen **1** is optimized for interdigitation and aligned aggregates are observed. The alignment is completely missing for compound **2** revealing steric problems. MD simulations for the neat compounds **1** and **2** and their 1 : 1 mixture confirm these findings. The simulations predict a considerable biaxiality parameter for nematic phases of compounds **1** but the absence of biaxiality for materials containing compounds **2**. These outcomes indicate that a detailed search within this family of molecules will lead probably to the discovery of the real biaxial nematic phase.

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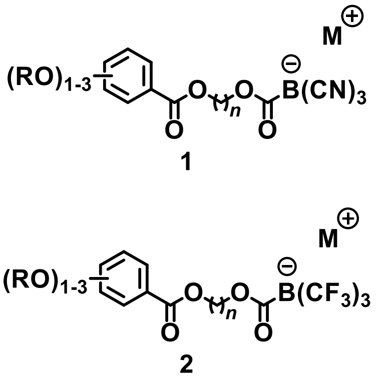
* Author for Correspondence: matthias.lehmann@uni-wuerzburg.de
nikolai.scheuring@uni-wuerzburg.de

Ionic liquid crystals with weakly coordinating borate anions

Pascal Weinberger[1], Guinevere Giffin[3], Jan Sprenger[2], Maik Finze[2], Matthias Lehmann[1*]

[1] Institut für Organische Chemie, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany
[2] Institut für Anorganische Chemie, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany
[3] Frauenhofer Institute for Silicate Research ISC, Neunerplatz 2, 97082 Würzburg, Germany

The high cohesive energy density difference between aliphatic and polar moieties of ionic liquid crystals (ILCs) leads almost exclusively to the formation of ordered lamellar, columnar or cubic mesophases. The ability to align these molecules in the liquid crystalline phase, combined with high ionic conductivity, makes ILCs particularly interesting for the use as electrolytes [1].



1

2

R = H, OC_mH_{2m+1}
M = $\mathrm{N}n\mathrm{Bu}_4$,
Na, K, Li,
Na⊂[18]crown 6,
K⊂[18]crown 6,
Li⊂[18]crown 6
m = 12, 14, 16, 18
n = 4, 10

Figure 1. Overview of the borate containing ionic liquid crystals.

Ionic liquid crystals with immobilized boron anions are rarely investigated [1b, 2]. Carboxy borates $[B(CN)_3COOH]^-$ and $[B(CF_3)_3COOH]^-$ are especially attractive since they are only weakly nucleophilic and a reduced interaction with counterions can be expected (Fig. 1) [3]. Merged with an aromatic unit, the anions can be practically immobilized while the cations remain to be the only mobile species. Thus, such materials can be considered as single-ion conductors. In the present study, these borates were linked via esterification to a peripheral non-polar building block with long aliphatic chains. The synthesis of ILCs with alkali metal cations is possible both in the presence and absence of a crown ether (Fig. 1). While varying the spacer length between the ionic and aliphatic units only leads to minor differences in the liquid crystalline phase behavior, changes in the cation and anion structure, as well as the number of attached chains, have a more significant effect. The liquid crystalline properties are investigated as a function of number and type of peripheral chains, the nature of the borate anions as well as cations ($\mathrm{N}n\mathrm{Bu}_4^+$; Na^+, K^+ or Li^+⊂[18]crown-6) and the spacer length by means of polarized optical microscopy, differential scanning calorimetry and X-ray scattering. The structure-property relationship for some selected samples is investigated with impedance spectroscopy which shows already encouraging mobility values for the cations.

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* Author for Correspondence: matthias.lehmann@uni-wuerzburg.de

Simulations of bent liquid crystal dimers: approaches to studying the twist-bend (N_{TB}) nematic phase

Mark R. Wilson[1*] and Gary Yu[1]

[1] Department of Chemistry, University of Durham, Durham DH1 3LE, UK

Certain liquid crystal dimers exhibit a nematic–nematic phase transition, with the lower temperature phase identified as the twist-bend (N_{TB}) nematic phase. The N_{TB} phase demonstrates emergent chirality from achiral molecules, with the spontaneous formation of a heliconical structure [1].

We present all-atom molecular dynamics simulations of CB7CB, which capture the N_{TB} phase and, upon heating, its transition into the nematic (N) and isotropic (I) phases [2]. Distributions of the bend angle and chirality order parameter, χ, are calculated for the ensemble of conformers in the simulated phases. We elucidate that CB7CB is statistically achiral but can adopt chiral conformers, with no preference for a specific handedness, and find that the extent of molecular chirality is unchanged between the N and the N_{TB} phases.

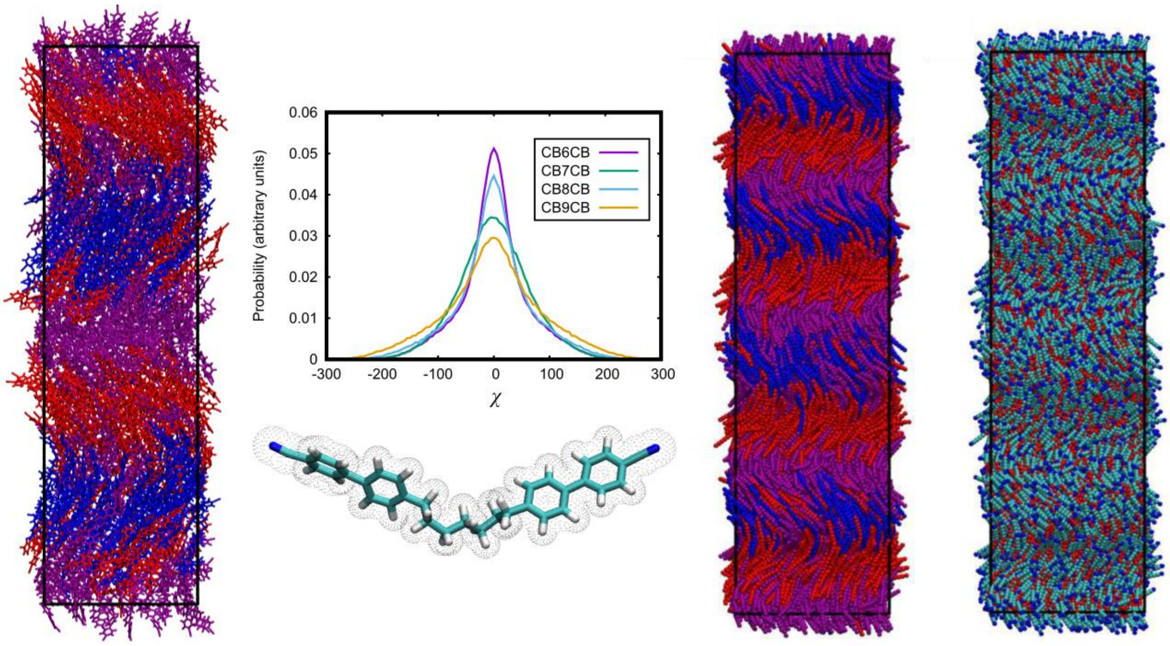

Figure 1: Left: Simulation snapshot from atomistic simulations of the N_{TB} phase for CB7CB. Centre: distributions of the chirality order parameter for CB*n*CB and a conformer of CB7CB with its molecular isosurface shown. Right: Snapshots from a coarse-grained model of the N_{TB} phase.

Single-molecule stochastic dynamics simulations expand the scope of the investigation to the dimer series CB*n*CB (n = 6-9) and CBX(CH_2)$_5$$Y$CB ($X$/$Y$ = CH_2, O or S). These confirm that the bent molecular shape determines the ability of a mesogen to form the N_{TB} phase rather than its potential to assume chiral conformers.

The all-atom calculations are used as a reference to produce a coarse-grained (CG) model of the N_{TB} phase of CB7CB using a hybrid force-matching approach [3]. We achieve good transferability of the CG model to other phases of CB7CB.

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* Author for Correspondence: mark.wilson@durham.ac.uk

Ferroelectric nematic liquid crystals on the rubbed alignment layer

Jeong-Seon Yu[1], Jae Hoon Lee[2], Jun-Yong Lee[1,2], and Jong-Hyun Kim[1,2]

[1]Institute of Quantum Sytems, Chungnam National University, Daejon, 34134, Korea
[2]Department of Physics, Chungnam National University, Daejon, 34134, Korea

Ferroelectric Nematic Liquid Crystal (FNLC) has spontaneous polarization in the director's direction. The potential for applications is enormous because it is susceptible to the electrical field with large dielectric constants and spontaneous polarization. The orientation properties of the FNLC indicate a difference from the conventional nematic liquid crystals. Although several studies have been reported on the alignment of FNLC, it is not yet fully understood [1-3].

Here, the orientation characteristics and the birefringence of FNLC-919 were investigated. It exhibits a ferroelectric nematic phase at room temperature, and its orientation characteristics vary depending on the rubbing conditions of both substrates. The liquid crystal (LC) uniformly aligned without domains in the cell where the two substrates were rubbed in the same direction. Two domains were observed in the cell where the two substrates were rubbed in opposite directions. The directors in the two domains were twisted in the opposite. We obtained the twist angle in each domain using the Jones matrix calculation. From electro-optical experiments, it was confirmed that the polarization is opposite to the rubbing direction.

The orientation characteristics differed between the nematic and FN phases in the 90° crossed rubbing cell. In the nematic phase, two domains twisted in opposite directions, whereas in the FN phase, only a twist of a direction was preferred in the entire cell. The twist direction and angle were obtained quantitatively.

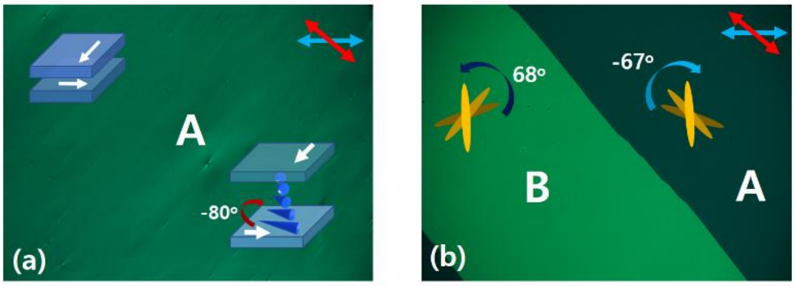

Figure 1. Schematic diagram of the twist direction for the director of the nematic and NF phase in a cell where the rubbing angle of the two substrates is 90°. (a) 25 °C, NF phase (b) 60 °C, nematic phase. Blue cones are directors of the NF phase and yellow round bars are directors of the nematic phase. Arrows indicate the orientation of the polarizer and analyzer.

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* Author for Correspondence: jxk97@cnu.ac.kr

Phase frustration and pattern formation in smectic films at the transition from the nematic phase

Bruno Zappone,[1*] Atilla E. Mamuk,[2] and Giuseppe Alì[3]

[1] Consiglio Nazionale delle Ricerche – Istituto di Nanotecnologia (CNR-Nanotec), 87036 - Rende, Italy
[2] Muğla Sitki Koçman University, Department of Physics, Muğla, Turkey
[3] Università della Calabria – Dipartimento di Fisica, 87036 - Rende, Italy

Spontaneous breaking of symmetry in liquid crystal (LC) often reveals itself as a microscopic pattern of molecular alignment. In a smectic-*A* LC, the emergence of positional order at the transition from the nematic phase leads to periodic textures that are used as optical micro-arrays, templates for soft lithography, and ordering matrices for organizing and manipulating functional nanoparticles. While both 1d and 2d patterns have been obtained as a function of the LC film thickness and applied fields, a clear connection has not been made between pattern formation and the peculiar critical behavior of LCs at the nematic-smectic transition, still eluding a comprehensive theoretical explanation. We demonstrate that an intense bend distortion applied to the LC molecular director while cooling from the nematic phase produces a frustrated smectic phase with depressed transition temperature, and a characteristic 1d periodic texture. In light of De Gennes' analogy with the normal-superconductor transition of a metal, we identify the 1d texture as the equivalent of the intermediate state in type-I superconductors. The bend distortion is analogue to the magnetic field in metals and penetrates in the frustrated phase as an array of undercooled nematic domains, periodically intermixed with bend-free smectic-A domains. Our findings provide fundamental evidence for theories of the nematic-smectic transition, highlighting the deep connection between phase frustration and pattern formation, and new perspectives to the design of functional smectic micro-arrays.

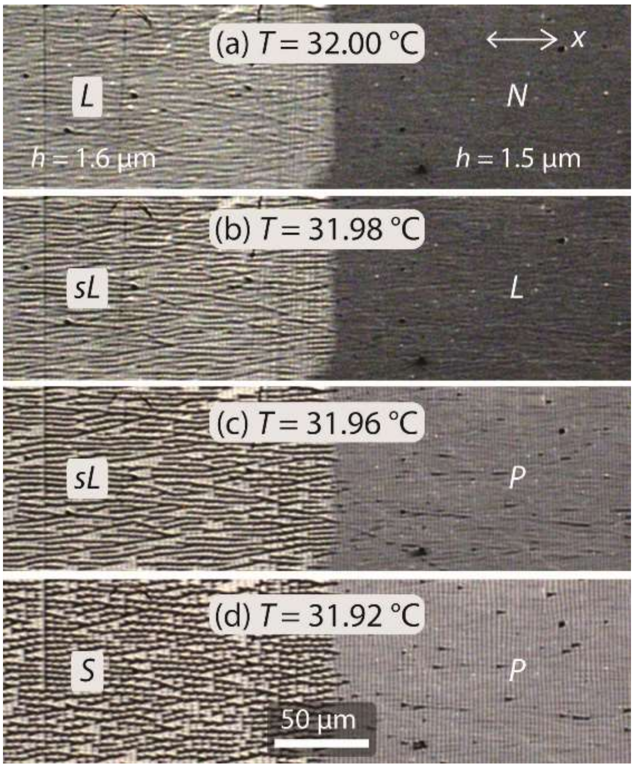

Figure 1. Textures observed upon cooling a thin 8CB film with conflicting homeotropic and planar anchoring conditions. *N* is the (untextured) nematic phase. *L* is a pretransitional texture of the nematic phase that evolves into the intermediate state (*P*) or the characteristic honeycomb texture of the smectic phase (*S*) under a strong or weak bend distortion, respectively.

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* Author for Correspondence: bruno.zappone@cnr.it

Optical Design of Energy Conversion Layer for high Photoelectric Conversion Efficiency of an Organic Solar Cell

Liang Zhang[1], Chul Gyu Jhun [1*]

[1,*] School of Semiconductor Engineering, Hoseo University, Asan 31499, Korea

Organic solar cells (OSCs) are devices that generate electricity from sunlight by utilizing organic materials to absorb sunlight and transport charges to generate photovoltaic effects. The photoelectric conversion efficiency (PCE) of OSCs is the most important device evaluation parameter, and many research groups have made a lot of efforts and attempts to improve the PCE of OSC[1].

In order to further improve PCE, the problem of the mismatch between the incident spectrum of sunlight and the absorption spectrum of the active layer of the OSC [2] should be solved. We designed energy conversion layers (ECLs) [3] to solve this problem. The proposed structure is shown in Fig. 1. The photoluminescent materials is used as ECL for energy conversion, further improving the PCE of OSC. The PCE of OSC was simulated by applying both the transfer matrix theory of multilayer thin films [4] and the theoretical formula of organic solar cells [5]. The reference device has the structure of Anode/HTL/PAL/HBL/Cathode and the proposed OSC device has the structure of Anode/HTL/ECL/PAL/HBL/Cathode. To verify the performance of proposed structure on the PCE of OSC, the PCE of both reference device and the proposed structure were simulated and compared. From the calculated results, the improvement of PCE of the OSC with the proposed structure is confirmed. We also fabricated the OSC device and evaluated its performance. The experimental results also consist with the simulation results.

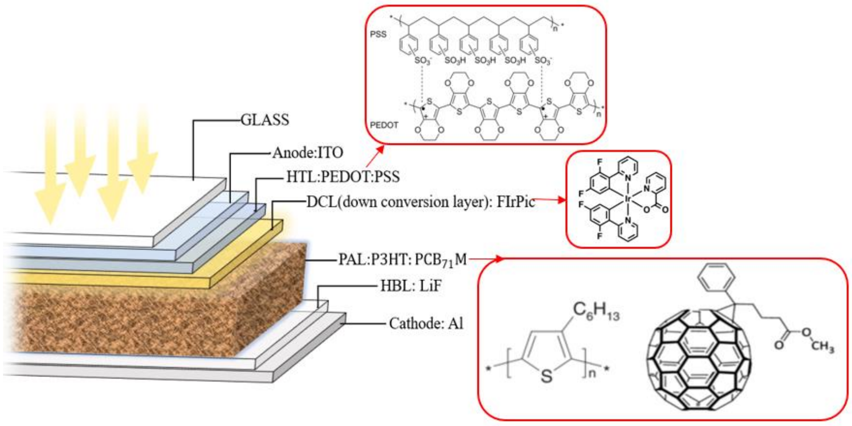

Figure 1. Optical design structure of organic solar cells and materials of each layer

Acknowledgement

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* Author for Correspondence: cgjhun@hoseo.edu

Indexes in Alphabetical Order of Submitter Divided for Sections

Plenary Speakers Index

Keynotes Speakers Index

Invited Speakers Index

Oral Contributions Index

Donato S.	O	9
Martella D.	O	9
Nocentini S.	O	9
Wiersma D.S.	O	9
Delaney C.	O	9
Florea L.	O	9
Parmeggiani C.	O	9

Emelyanenko A.	O	10
Rudyak V.	O	10
Shvetsov S.	O	10
Araoka F.	O	10
Nishikawa H.	O	10
Ishikawa K.	O	10

Erkoreka A.	O	11
Martinez-Perdiguero J.	O	11
Mandle R.J.	O	11
Mertelj A.	O	11
Sebastián N.	O	11

Essaoui L.	O	13
Niyonzima J.	O	13
Tosarelli C.	O	13
Abadie C.	O	13
Jeridi H.	O	13
Vlad A.	O	13
Coati A.	O	13
Royer S.	O	13
Constantin D.	O	13
Vickridge I.	O	13
Goldmann M.	O	13
Garreau Y.	O	13
Babonneau D.	O	13
Croset B.	O	13
Lhuilier E.	O	13
Lacaze E.	O	13

Revignas D.	O	15
De Michele C.	O	15
Ferrarini A.	O	15

Lavrič M.	O	28
Rešetič A.	O	28
Črešnar D.	O	28
Derets N.	O	28
Zalar B.	O	28
Rožič B.	O	28
Kutnjak Z.	O	28

Lehmann M.	O	29
Scheuring N.	O	29
Singh D.	O	29
Figueirinhas J.	O	29
Sebastião P.	O	29
Cruz C.	O	29
Mandle R.	O	29

Liu S.	O	31
Nys I.	O	31
Neyts K.	O	31

Podoliak N.	O	33
Membrillo Solis I.	O	33
Madeleine T.	O	33
D'Alessandro G.	O	33
Kaczmarek M.	O	33
Orlova T.	O	33
Brodzki J.	O	33

Marinčič M.	O	35
Pišljar J.	O	35
Ghosh S.	O	35
Turlapati S.	O	35
Rao N.V.S.	O	35
Škarabot M.	O	35
Mertelj A.	O	35
Petelin A.	O	35
Nych A.	O	35
Pusovnik A.	O	35
Muševič I.	O	35
Ravnik M.	O	35

Poster Contributions Index

Lee S.J.	P	24
Kim W.Y.	P	24
Jhun C.G.	P	24

Noll K.	P	25
Lehmann M.	P	25

Basim Atata S.	P	26
Lelidis I.	P	26

Zhang X.	P	27
Wang Y.	P	27
Sun S.	P	27
Zhang Y.	P	27
Liu Y.	P	27

Nikolova D.	P	28
Tipping P.J.	P	28
Mandle R.	P	28
Gleeson H.F.	P	28

Orlova T.	P	29
Lobanov I.S.	P	29
Tambovtsev I.M.	P	29
Lancia F.	P	29
Iamsaard S.	P	29
Katsonis N.	P	29
Kiselev A.D.	P	29
Uzdin V.M.	P	29
Brasselet E.	P	29

Osipov M.A.	P	30
Merekalov A.S.	P	30
Ezhov A.A.	P	30

Morawiak P.	P	31
Maur R.	P	31
Oton E.	P	31
Muszyński M.	P	31
Szczytko J.	P	31
Kula P.	P	31
Piecek W.	P	31

Shimizu Y.	P	39
Kawano K.	P	39
Yamamoto M.	P	39
Uchida K.	P	39
Ohta N.	P	39
Kawai T.	P	39
Fujii A.	P	39
Ozaki M.	P	39

Spina L.	P	40
Ciuchi F.	P	40
Tone C.M.	P	40
Barberi R.C.	P	40
De Santo M.P.	P	40

Štanc R.	P	41
Xu Y.	P	41
Dupont R.	P	41
Wang X.	P	41
Čopar S.	P	41
Tkalec U.	P	41

Szarek M.	P	43
Kamer A.	P	43
Czerwiński M.	P	43
Kula P.	P	43

Katranchev B.	P	45
Petrov M.	P	45
Naradikian H.	P	45
Vlakhov T.	P	45
Castriota M.	P	45

Weinberger P.	P	47
Scheuring N.	P	47
Mandle R.	P	47
Lehmann M.	P	47

Weinberger P.	P	49
Giffin G.	P	49
Sprenger J.	P	49
Finze M.	P	49
Lehmann M.	P	49

Indexes in Alphabetical Order of Authors Divided for Sections

Plenary Speakers Index of Authors

Keynotes Speakers Index of Authors

Invited Speakers Index of Authors

Oral Contributions Index of Authors

Poster Contributions Index of Authors