



ESF Exploratory Workshop on

Frontiers in European Research on Liquid Crystalline Soft Matter

May 26 - 29, 2009

LC Lab, Bandol
France

Book of Abstracts



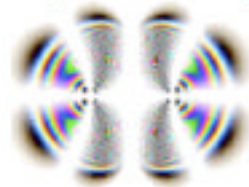
**Exploratory Workshop
Scheme**

Standing Committee for Life, Earth
and Environmental Sciences
(LESC)

Standing Committee for Physical
and Engineering Sciences (PESC)

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**International Liquid
Crystal Society**



Soft Matter

In bringing together world-class European scientists representing different perspectives of liquid crystalline soft matter research, we wish to stimulate discussion around the future directions for the field, currently in an exciting exploratory phase of transformation. Several innovative, often interdisciplinary, themes are today developing, where liquid crystals meet e.g. biotechnology, colloids or photovoltaics. This workshop aims to contribute to the structuring of this process, aiding in producing a viable strategy for European researchers.

Workshop web site: www.workshop.lcsoftmatter.com

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The case for an exploratory workshop

Background

In the development of the understanding of the liquid crystalline state of matter, Europe has had central role. This applies on the one hand in terms of fundamental research¹, seminal contributions given by e.g. the Germans REINITZER, LEHMANN, VORLÄNDER, SAUPE and HELFRICH, the French MAUGUIN, GRANDJEAN, FRIEDEL and DE GENNES, the UK researchers BERNAL, FRANK and LESLIE, the Swede OSEEN, the Pole MIESOWICZ and the Italian LUZZATI. In terms of the commercial exploitation, Europe's chemistry industry has long been and still is very active, the efforts of e.g. Merck, BDH and Roche having been fundamental for building up today's highly successful liquid crystal display industry, whereas companies like Unilever and Nestlé were early in exploring the potential of lyotropic liquid crystals for enhancing every-day products like detergents, processed foods or pharmaceuticals.

Liquid crystals—sometimes referred to as anisotropic fluids—are thermodynamically stable phases between the crystalline solid state and the ordinary isotropic liquid, exhibiting a manifold of unique properties that are deeply fascinating as well as highly useful. Although more or less fluid, liquid crystals exhibit partial order with long-range orientational correlation and, in the cases of smectic/lamellar, hexagonal columnar and cubic phases, also a quasi-long range translational correlation in one, two and three dimensions, respectively. The structures are formed through the self-organisation of anisometric molecules (thermotropic liquid crystals) or of aggregates of amphiphilic molecules—e.g. phospholipids in living tissue or surfactants in detergents—or anisometric colloidal particles in a solvent (lyotropic liquid crystals). The main application of the former class is in liquid crystal displays (LCDs) while lyotropics so far are employed commercially foremost in detergents and in the cosmetic, pharmaceutical and food industries. In both cases, the industries in question belong to the multi-billion-euro category.

An exciting stage of new developments

Today, the display-related themes that for many years have dominated research in the core liquid crystal community are receiving less attention in academia, such research now largely being driven by industry. Instead, several new topics are sprouting, focusing on entirely different issues. While the immense commercial success of flat panel LC displays has brought the concept *liquid crystal* to the broad public, these ordered fluids actually play a fundamental role and have great application potential also in very different contexts, e.g. in biology and biotechnology, materials science and nanotechnology. The lamellar liquid crystalline state of cell membranes (internal and external) is crucial to the cell's biological functions. DNA-based nucleosome core particles have been found to

¹ T. J. Sluckin, D.A. Dunmur, and H. Stegemeyer, Crystals that flow: Classic papers from the history of liquid crystals, (Taylor and Francis, London, 2004).

exhibit a rich liquid crystalline polymorphism under biologically relevant conditions. The function of the inorganic components in biomaterials—natural as in the skeleton or artificial as in implants—can depend sensitively on liquid crystalline properties of precursors or even of the components themselves. A famous example where liquid crystalline properties have been used to produce a commercially successful synthetic material is the super strong fibre Kevlar® and in nature we find similar liquid crystal-related materials in spider webs and in silk, from which several lessons are still to learn and which therefore are the focus of intense current research. These roles are still poorly exploited and they are likely to be at the focus of much of tomorrow's liquid crystal-related research.

New frontiers

A number of totally new ways of applying liquid crystals and the self-assembly processes underlying their formation are currently being developed or proposed, e.g. in advanced materials templated from liquid crystals², organic electronic and/or photoconductive components³, actuators⁴, sensors⁵, photonic crystals and metamaterials⁶, delayed-release drug delivery systems⁷ etc. New fascinating research themes are continuously being opened, spanning liquid crystal, colloid and polymer science, bio- and nanotechnology, and resulting in an extremely rich scientific-technological playground.

While this is a very exciting era of exploration and broadening for European liquid crystal research, leaving traditional borders of liquid crystal science obsolete, it can be difficult to define a clear focus. Many different opinions—sometimes conflicting—regarding the most prosperous strategies for the continued development coexist. It seems likely that future liquid crystal research will rarely be conducted strictly as such, the research topics with the greatest potential being of strongly interdisciplinary character, dealing with liquid crystal-

² G. Armatas & M. Kanatzidis, 'Hexagonal mesoporous germanium', *Science* **313**, 817 (2006); J. Baumberg, 'Breaking the mould: Casting on the nanometre scale', *Nature Mater.* **5**, 2 (2006); J. Hulvat and S. Stupp, 'Anisotropic properties of conducting polymers prepared by liquid crystal templating', *Adv. Mater.* **16**, 589 (2004); G. Scalia, C. von Bühler, C. Hägele, S. Roth, F. Giesselmann, and J.P.F. Lagerwall, 'Spontaneous macroscopic carbon nanotube alignment via colloidal suspension in hexagonal columnar lyotropic liquid crystals', *Soft Matter*, **4**, 570 (2008)

³ Y. Yamamoto et al., 'Photoconductive coaxial nanotubes of molecularly connected electron donor and acceptor layers', *Science* **314**, 1761 (2006); V. Lemaire et al., 'Charge transport properties in discotic liquid crystals: A quantum-chemical insight into structure-property relationships', *J. Am. Chem. Soc.* **126**, 3271 (2004); M. O'Neill & S. Kelly, 'Liquid crystals for charge transport, luminescence, and photonics', *Adv. Mater.* **15**, 1135 (2003)

⁴ S. Courty, J. Mine, A. Tajbakhsh & E. Terentjev, 'Nematic elastomers with aligned carbon nanotubes: New electromechanical actuators', *Europhys. Lett.* **64**, 654 (2003); M. Li, P. Keller, B. Li, X. Wang & M. Brunet, 'Light-driven side-on nematic elastomer actuators', *Adv. Mater.* **15**, 569 (2003)

⁵ D. M. Walba, L. Eshdat, E. Körblova, R. F. Shao & N. A. Clark, 'A general method for measurement of enantiomeric excess by using electrooptics in ferroelectric liquid crystals', *Angew. Chem. (Int. Ed.)* **46**, 1473 (2007); J. Brake, M. Daschner, Y. Luk & N. Abbott, 'Biomolecular interactions at phospholipid-decorated surfaces of liquid crystals', *Science* **302**, 2094 (2003)

⁶ C. Rockstuhl, F. Lederer, C. Etrich, T. Pertsch & T. Scharf, 'Design of an artificial three-dimensional composite metamaterial with magnetic resonances in the visible range of the electromagnetic spectrum', *Phys. Rev. Lett.* **99**, 017401 (2007); J. Hwang et al., 'Electro-tunable optical diode based on photonic bandgap liquid-crystal heterojunctions', *Nature Mater.* **4**, 383 (2005); I. Musevic, M. Skarabot, U. Tkalec, M. Ravnik & S. Zumer, 'Two-dimensional nematic colloidal crystals self-assembled by topological defects', *Science* **313**, 954 (2006)

⁷ M. Malmsten, 'Soft drug delivery systems', *Soft Matter* **2**, 760 (2006); J. Barauskas, M. Johnsson & F. Tiberg, 'Self-assembled lipid superstructures: beyond vesicles and liposomes.', *Nano. Lett.* **5**, 1615 (2005)

related aspects of e.g. biology and biotechnology, materials development, semiconductor device science or micro- and nanofluidics. The most promising approach is probably to conduct liquid crystal research as an integrated part of the broad field of soft matter physics and chemistry, currently growing strongly in interest worldwide with Europe being one of the main players. Indeed, as was pointed out by one of the founding fathers of the field, Pierre-Gilles de Gennes, liquid crystals constitute an archetypal category of soft matter, displaying a fantastic breadth in terms of structures, materials and functions⁸.

⁸ P. G. de Gennes, 'Soft matter: more than words', *Soft Matter* **1**, 16 (2005)

Main Objectives of the Workshop

1. To obtain an overview of current innovative European research in the realm of soft condensed matter that addresses, applies or relies on aspects of the liquid crystalline state of matter and its formation processes,
2. to bring together a small group of leading European scientists representative of different sub-disciplines of soft matter research where liquid crystallinity plays a role, thereby cross-fertilizing activities which so far are often not as much in contact as could be beneficial,
3. to sow the first seeds for new European research networks on strategically relevant topics in the field, and to distinguish those with the best prospects of producing a valuable contribution to society, addressing issues relevant to e.g. health, energy, advanced technologies etc.,
4. to contribute to the definition of a 'road map' for focused future development of European research on liquid crystalline soft matter, taking academic as well as industrial perspectives into account, thereby strengthening Europe's position in this rapidly growing multidisciplinary research field.

Workshop Agenda

The scientific program comprises three main components:

1. SCIENTIFIC RESEARCH PRESENTATIONS

—*Sharing of expertise* (contributing to objectives 1 and 2)

Each participant is given 30 or 40 minutes (the latter for the five keynote lecturers) for a presentation related to her/his research, including discussion. Because of the multidisciplinary nature of the meeting, all speakers are requested to provide presentation abstracts at the latest three weeks prior to the workshop, in order to promote a lively and creative discussion. These abstracts will be made publically available via the workshop web page. As soon as the convenors have received all abstracts they will compile them into a program that will then be sent directly to all workshop participants via e-mail.

2. RESEARCH NETWORK DISCUSSIONS

—*Identifying topics benefiting from collaboration* (objective 3)

In line with the general guidelines for ESF exploratory workshops, a prime aim will be to develop new ideas for collaborative actions and/or other follow-up activities. The workshop program comprises three one-hour sessions devoted to open discussions around European research network initiatives. All participants are given the opportunity to provide proposals for such initiatives that will be circulated in advance of the workshop, thereby providing a foundation for these discussions. Those who wish to contribute are requested to formulate a tentative title and a half-page summary of the main ideas, background and motivation at the latest two weeks prior to the workshop start. Doing so does not oblige to also coordinate the action; suitable coordinators and participants (of course extending well beyond the small group of workshop participants) of future activities will be identified during the discussions.

3. SUMMARIES AND STRATEGIC DISCUSSIONS

—*Recognising target activities* (objective 4)

Specific time slots have been allocated at the end of each of the five thematic sessions for discussions summarising the presentations, as well as giving an outlook for future research on the topics addressed. The workshop ends with a 90-minute session devoted to summarising the whole meeting and outlining viable strategies for future European research in the field.

Report publication and dissemination

A full meeting report for the ESF, concisely summarising the scientific/strategic output of the workshop, will be written by the organisers at the latest two months after the end of the meeting. It will then be distributed to all participants in digital format. A number of journals have been contacted regarding the possibility to publish brief reports after the workshop and *Nature Materials*, *ChemPhysChem* and *Europhysics News* have responded positively. The journal reports should not necessarily be authored by the organisers but can be prepared by any of the participants (two co-authors with complementary expertise and interests ought to be ideal). The distribution of these writing tasks will be handled at the meeting.

We are particularly grateful to *Nature Materials* for having their Senior Editor Dr. Victoria Cleave present as an observer throughout the meeting.

Some words on the meeting location

LC Lab Bandol is a small convention centre built around a lab equipped for basic liquid crystal research. In 2004 it hosted its first international scientific workshop and since 2006 it hosts a yearly summer school on liquid crystals, both with an extremely appreciative audience. The location in the centre of the city, yet very close to the sea with beautiful views of the Mediterranean, gives each event organised at the LC Lab Bandol a very inspiring and creative atmosphere. The small scale and generous discussion sessions will enhance close contacts between participants.

The experimental facilities available in the lab allows unique experimental components of the presentations, and ideas generated during discussions can in some cases immediately be put to simple tests under the microscope. Standard conference equipment such as computer with projector, internet, printing and copying facilities, whiteboard, flip chart etc. are of course all available.

Workshop program

The scientific program will run Wednesday 27th to Friday 29th of May. Keynote lectures last 30 minutes, all other lectures 20 minutes. Every lecture is followed by 10 minutes questions and discussion. In the evenings of Tuesday May 26th and Friday May 29th all attendants are invited to get-together and farewell buffet dinners, respectively.



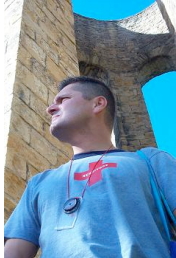


Wednesday May 27 th		Thursday May 28 th		Friday May 29 th	
09:15	Opening (Lagerwall)	09.00	Olsson	09.00	Zannoni
Session i: Liquid crystals in and from living matter and in medicine [Chair: Olsson]		09.30	Summarizing discussion to session ii	09.30	Mitov
09.40	Livolant (Keynote)	10.00	Coffee / tea	10.00	Gießelmann
10.20	Bellini	Session iii: Liquid crystal colloids and colloidal liquid crystals [Chair: Zannoni]		10.30	Summarizing discussion to session iv
10.50	Coffee / tea	10.30	Musevic (Keynote)	11.00	Coffee / tea
11.20	Bouligand	11.10	Scalia	Session v: Liquid crystals in sensors, actuators and novel optic and electrooptic devices [Chair: Mitov]	
11.50	Edwards	11.40	Blanc	11.30	Warner (Keynote)
12.20	Summarizing discussion to session i	12.10	Lunch	12.10	Dierking
12.50	Lunch	14.00	van der Schoot	12.40	Lunch
Session ii: Drops, bubbles, tubes, foams and films [Chairs: Rudquist/Edwards]		14.30	Vroege	14.30	Rudquist
14.30	Quéré (Keynote)	15.00	Summarizing discussion to session iii	15.00	Gleeson
15.10	Stannarius	15.30	Coffee / tea	15.30	Summarizing discussion to session v
15.40	Coffee / tea	Session iv: Liquid crystals for new functional materials, organic electronics and photovoltaics [Chair: Gleeson]		16.00	EU initiatives brainstorm (with coffee/tea)
16.10	Orwar	16.00	Tschierske (Keynote)	17.00	Workshop summary & strategic planning
16.40	Holyst	16.40	O'Neill	18.30	Workshop closing
17.10-18.10	EU initiatives brainstorm	17.10	ESF Information (Ruud)	20.00	Farewell buffet
		17.30-18.30	EU initiatives brainstorm		




Meet the speakers

	<p>Tommaso G. Bellini, born in 1961, completed his PhD in Physics in 1989 at the University of Pavia, Italy, under the guidance of V. Degiorgio. After a postdoctoral stay with N.A. Clark at the University of Colorado, he was appointed Researcher in Condensed Matter at the University of Pavia (1992), associate Professor in General Physics at the Politecnico di Milano (1999), full Professor in Applied Physics at the University of Milano (2002), where he has joined the Faculty of Medicine. His experimental activity in the field of bio-soft matter includes: liquid crystals in confinement, electrokinetics of colloids, self-assembly of oligonucleotides, novel concepts for label-free biosensors.</p>
	<p>Christophe Blanc graduated from Ecole Normale Supérieure de Lyon and received PhD degree (2000) in solid state physics from Pierre et Marie Curie University. Since 2001 he has a permanent position in CNRS at Montpellier in Laboratoire des Colloïdes, Verres et Nanomatériaux where he works in the Soft Matter group. During the recent years, his interests have focused on the dynamics of liquid crystals defects, the dynamical properties of anchoring, but also on new materials based on liquid crystal composites.</p>
	<p>Yves Bouligand studied biology at the ENS, rue d'Ulm, and received his PhD from the University of Paris 6. After a postdoctoral year in Bristol, he joined the Ecole Pratique des Hautes Etudes and the Centre de Cytologie Expérimentale, a CNRS unit near Paris. His research was first pure zoology, mainly parasites (crustaceans) and symbionts (xanthellae) of corals. Microscopy was essential to analyse the inner geometry of foraminifera or chromosomes. Though very different, these materials had in common to be made of long polymers (chitin or DNA) showing a cholesteric order. Liquid crystals with their defects and textures were then investigated as models of precise morphogenetic processes in biological systems.</p>
	<p>The research interests of Ingo Dierking (Diploma in Physics 1992, Dr rer. nat 1995, Habilitation 2002, Senior Lecturer / Associate Professor since 2005) lie in the general field of Soft Matter Physics, especially chirality in liquid crystals, polymer modified liquid crystal composites, liquid crystal - micro- and nano-particle dispersions, growth and coarsening phenomena, and fractal structures in soft and biological matter.</p>
	<p>Katarina Edwards is professor in physical chemistry at Uppsala University. Her previous research has mainly concerned structure, dynamics, and phase behaviour in lipid/surfactant systems. The scientific activities have frequently been directed towards issues and systems of pharmaceutical, medical and biotechnical relevance. Special emphasis has been put on development and characterization of liposomes, and related self assembled aggregates, intended for drug delivery. Present research activities include the development of liposomes for targeted radio-nuclide therapy, mechanistic studies of lipid-peptide interactions, and development and optimization of a novel type of polymer-stabilized nanodisks for pharmaceutical and analytical applications.</p>



	<p>Frank Giesselmann studied chemistry and received his PhD from the Technische Universität Clausthal-Zellerfeld. During his post-doctoral studies on phase transitions in liquid crystals, he worked with Peter Zugenmaier (Clausthal), W. Kuczynski (Poland), and Sven T. Lagerwall (Sweden). In 1998 he finished his habilitation and received the <i>venia legendi</i> in Physical Chemistry. Since 2002 he has been Professor of Physical Chemistry at the Universität Stuttgart, where he also joined the International Max Planck Research School on Advanced Materials. His foremost research interest is the liquid crystalline state of matter including the structure and dynamics, the phase transitions, and the electrical/optical properties of both thermotropic and lyotropic liquid-crystalline phases.</p>
	<p>Helen Gleeson gained her PhD in Physics from Manchester in 1986, joined their academic staff in 1989 and is now the Head of the School. She is an experimentalist whose research interests include optical properties of liquid crystals, laser interactions with LC droplets, structural studies of chiral systems, and most recently biaxial nematics. She is also interested in using LCs in non-device configurations, e.g. as sensors. Helen's past roles have included Chair of the British Liquid Crystal Society, Editor of <i>Liquid Crystals Today</i> and Chair of the ILCS Honours and Awards Committee. She is currently the Vice Chairman of the ILCS. Helen has published more than 110 papers and made over 250 conference presentations.</p>
	<p>Robert Holyst graduated from Warsaw University (physics) in 1986 and after PhD (chemistry) in 1989 and habilitation (1992) he became full professor in 1998. He has worked in the USA (University of Washington), France (Ecole Normale Supérieure) and Germany (Max Planck Institute Mainz) and collaborated with industrial partners (Mitsui Chemicals Inc., Unilever, Samsung). His scientific interests range from statistical mechanics to soft matter, biophysics and biochemistry (both theory and experiment). He is a coauthor of 160 scientific papers, two books and five patents. He is currently a professor and scientific director at the Institute of Physical Chemistry PAS and a professor at the Cardinal Stefan Wyszyński University in Warsaw.</p>
	<p>Françoise Livolant completed her "Doctorat de 3ème cycle" in 1977 and her "Doctorat d'Etat" in 1981 in biology and biophysics at the University Paris-VI, France, under the guidance of Yves Bouligand. She got a permanent position at the CNRS in 1979 and worked at the Centre de Biologie Cellulaire, Ivry-sur-Seine (France) until 1994 when she moved to the Laboratoire de Physique des Solides in Orsay. She started her own group to study the structure and function of condensed states of DNA and chromatin. A special attention is paid to polyelectrolyte and structural aspects of model systems (DNA, nucleosomes etc.) that can be used to help understand the functional activity of the genetic material <i>in vivo</i> (ejection of DNA from the bacteriophage, structure of chromatin in the cell nucleus, etc.).</p>
	<p>Annette Meister received her PhD in Inorganic Chemistry in 1994 at the University of Neuchâtel in Switzerland. After a postdoctoral stay at the Martin-Luther-University Halle-Wittenberg (1999-2000), the Max Planck Institute of Colloid and Interface Science in Potsdam (2001) and the CEA Saclay in France (2002) she joined the group of A. Blume at the Martin-Luther-University Halle-Wittenberg (2003, Habilitation 2008). Her current experimental activity in the field of soft matter includes: self-assembly of bolaamphiphiles, interfacial behaviour of lipids and surfactants at the air-water interface and interaction of peptides and proteins with lipid monolayers studied with Infrared Reflection Absorption Spectroscopy.</p>

	<p>Michel Mitov received his PhD in Condensed Matter Physics from the Univ. of Nice-Sophia Antipolis (France). After a postdoctoral period at Chalmers Univ. of Technology in Göteborg (Sweden), he got a permanent position at CNRS-CEMES in Toulouse (France) where he is the leader of the LC Physics team. His interests have focused on optical and structural properties of cholesteric LCs (CLCs) and Polymer-Stabilized CLCs. He is working on unusual features of the Bragg light reflection (How to broaden the wavelength bandwidth ? How to go beyond the reflectance limit ?) and the self assembly of nanoparticles and nanotubes in CLCs. He is the author of two monographs on LCs (2000) and soft matter (2009, forthcoming).</p>
	<p>Igor Muševič received his BsC and PhD degrees in physics at the University of Ljubljana. He was a visiting scientist at the University of Nijmegen, The Netherlands, and Max Planck Institute in Grenoble. He is a Professor of Physics at the University of Ljubljana and the Head of Condensed Matter Physics Department at J. Stefan Institute in Ljubljana. His research interests include physics of ferroelectric liquid crystals, behaviour of liquid crystals in high magnetic fields, optical spectroscopy, forces generated by complex fluids, self-assembly in liquid crystal colloids and single atom manipulation at low temperatures. He is the recipient of several national and international scientific awards.</p>
	<p>Mary O'Neill received her PhD in Physics from the University of Strathclyde. After a postdoctoral fellowship at the University of Glasgow and a short spell in industry, she joined the University of Hull. She is currently Professor of Physics and is joint leader of an interdisciplinary team investigating photonic and optoelectronic applications for semiconducting liquid crystals. Other research interests include the photoalignment of liquid crystals and hybrid inorganic-organic optoelectronic devices.</p>
	<p>Ulf Olsson is a professor in Physical Chemistry at Lund University. He obtained his PhD in Lund 1988. After a year as a post-doctoral fellow at Centre Paul Pascal, Pessac (Bordeaux), he returned to Lund at the end of 1989, and has remained there, at the division of Physical Chemistry, ever since. His research interest has for a long time been focused on surfactant self-assembly and microemulsions involving self-assembly structure, phase equilibria and structural transformation kinetics. Experimental methods involve mainly various NMR and scattering methods. Since recently, his research interests also includes the self-assembly of peptides and other biomolecules.</p>
	<p>Owe Orwar</p>
	<p>David Quéré</p>

	<p>Per Rudquist gained his PhD in Physics in 1997 at Chalmers University of Technology. In 1999-2000 he spent several periods at the University of Colorado at Boulder. Rudquist is since 2004 Associate Professor at the department of Microtechnology and Nanoscience at Chalmers. His research includes optics, electrooptics, and physics in general of chiral thermotropic liquid crystals with special focus on ferroelectric and antiferroelectric systems. Recently he has also started activities in using liquid crystal materials for sensing applications, e.g. chiral detection and measurements of enantiomeric excess in chiral pharmaceuticals. Rudquist is on the Board of Directors of the International Liquid Crystal Society. He has published about 70 scientific papers and book chapters, e.g. the chapter on Smectic LCD Modes in the forthcoming Handbook of Visual Displays.</p>
	<p>Giusy Scalia received her PhD in Physics at Chalmers University of Technology, Gothenburg, Sweden in 2002. Directly afterwards she took on a researcher position at the Italian National Agency for New Technologies, Energy and the Environment (ENEA). In 2004 she was guest researcher at the Institute of Physical Chemistry, University of Stuttgart, Germany, funded by the Swedish Research Council (VR). In 2006-2007 she worked as a research associate at the Max Planck Institute for Solid State Physics, Stuttgart, Germany, holding a Marie Curie Intra-European fellowship. Her research interests range from the optical properties of liquid crystals, including photoconductivity, to the optical and electrical properties of carbon nanotubes, fullerenes and graphene, and their composites with liquid crystals.</p>
	<p>Paul van der Schoot obtained his doctorate at the Delft University of Technology, Netherlands, in 1992, worked as a postdoctoral researcher at the Cavendish Laboratory in Cambridge, UK, from 1992 to 1995, the Max Planck Institute for Colloids and Interfaces in Teltow-Seehof, Germany, from 1995 to 1998, and the Van't Hoff Laboratory in Utrecht, Netherlands, from 1998 to 1999. From 1999 he has been employed as a lecturer at the Eindhoven University of Technology. He specializes in soft matter theory, in particular of colloids, liquid crystals and supramolecular polymers.</p>
	<p>Ralf Stannarius</p> <ul style="list-style-type: none"> • studied Physics at Leipzig University, PhD in 1985 (NMR-Spectroscopy of Liquid Crystals), • 1985-2003 assistant professor in Leipzig, • since 2003 full professor for experimental physics (Dept. of Nonlinear Phenomena) at the Otto-von-Guericke University in Magdeburg, • fields of interest: nonlinear phenomena, self organization and pattern formation in physical, chemical and biological systems, hydrodynamics of complex liquids, liquid crystals, granular matter and ferrofluids, LC elastomers and gels, LC colloids. • Books: 'Molecules in interaction with surfaces' (Lecture Notes in Physics), 2004, ed., 'Kompaktkurs Physik' 2004 with H. Pfeifer and H. Schmiedel.
	<p>Carsten Tschierske received his PhD in Organic Chemistry in 1985 at the University of Halle. After habilitation and several visitor professorships he was appointed in 1994 as Professor of Organic Chemistry/Supramolecular Chemistry at the Martin-Luther-University Halle-Wittenberg, Halle, Germany. His primary research interest is focussed on the design of new materials forming complex self organised soft-matter structures.</p>

	<p>Gert Jan Vroege obtained his doctorate on the theory of lyotropic liquid crystal polymers in the group of Theo Odijk at Delft University of Technology, The Netherlands, in 1989. He worked on thermotropic polymer liquid crystals as a researcher at the Institute for Polymer Materials TNO, and has been employed as a (senior) lecturer/researcher since 1992 at the Van't Hoff Laboratory for Physical and Colloid Chemistry, Utrecht University, The Netherlands. Since 2004, he has also been a fellow of University College Utrecht. His current field of interest comprises experiments and theory of colloids, in particular mineral liquid crystals.</p>
	<p>Mark Warner is a theoretical physicist at the Cavendish Laboratory, Cambridge University. His main interests are in liquid crystal elastomers. With Professor EM Terentjev, he has written a research monograph "Liquid Crystal Elastomers" (OUP, paperback edition, 2007). He has predicted or modelled phenomena such as in nematics huge thermal and optical elongations (including polarisation dependence), low cost shape change associated with director rotation ("soft elasticity"); chiral-mechanical response in cholesteric elastomers; and complex mechanics in smectics.</p>
	<p>Claudio Zannoni received his PhD in Chemical Physics at Southampton University, UK, in 1975. He is Full Professor of Physical Chemistry of Materials (1987-) and Director of the Department of Physical Chemistry at Bologna University, IT. He also directs the International School of Liquid Crystals, Erice, IT, since 1998. His research interests include Modeling and Computer Simulations and the use of Spectroscopic Techniques to investigate bulk and nanoconfined Liquid Crystals, Polymers, Proteins and other Soft Materials. He is an author of over 200 papers and has given more than 200 invited lectures on these topics.</p>

The organizers

	<p>Jan Lagerwall obtained his M.Sc. in Physics in 1997 and Ph.D. in Materials Science in 2002, both at Chalmers, Göteborg, Sweden. After post-docs at the CU Boulder (CO, USA), TU-Berlin and University of Stuttgart (Germany), he took on a position as junior research group leader at the MLU Halle-Wittenberg in Halle, Germany, in 2007. His research interests lie in the realm of soft matter, particularly liquid crystals. Current projects focus on liquid crystal–nanotube composites, microfluidics, phospholipid aggregate morphologies and electrospinning.</p>
	<p>Sven Lagerwall graduated from Chalmers University of Technology in 1958 with a major in Nuclear Engineering, after which he continued his studies at Hahn-Meitner Institute for Nuclear Research in Berlin-Wannsee, obtaining his PhD in 1964. After his habilitation at Chalmers in 1966 he was appointed lecturer there and became full professor 1986. He changed his research interests in 1972 when he was able to visit the Orsay Group under Pierre-Gilles de Gennes in Paris for more than a year. His research interests have been focused mainly on disclinations and dislocations as well as polar effects in liquid crystals, i. e. para-, ferro-, antiferro- and flexoelectricity.</p>

Abstracts



Session i. Liquid crystals in and from living matter and in medicine

How to use the bacteriophage system to analyze the structure and phase transitions of DNA in and out of the capsid

F. Livolant, A. Leforestier



Françoise Livolant

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The DNA molecule is known to form multiple ordered phases (mesophases or 3D crystals) in solution, whose nature depends on its concentration and ionic environment [1]. Similar organizations were found *in vivo* in chromosomes, sperm nuclei and virus capsids [2]. We focus here on bacteriophage DNA. Bacteriophages are complex macromolecular machineries that deliver their genome into the bacteria while their capsid and tail remain outside. DNA ejection is triggered by specific interactions of the extremity of the tail with a receptor inserted in the wall of the bacteria. DNA, initially at a concentration close to 500 mg/ml in the full capsid, progresses in the tail and is injected into the cytoplasm. In a few cases, the bacterial receptor has been isolated and DNA can be ejected in solution [3]. This simplified system can be used to investigate the underlying mechanisms of bacteriophage ejection [4] and also to study the condensed states of DNA inside and outside of the capsid. We used the T5 bacteriophage with a 80 nm diameter capsid containing 113.9 kbp DNA (almost 40 μ m long).

Using cryoElectron microscopy (cryoEM), we follow the organization of DNA inside the capsid at different steps of the ejection process. The DNA chain decreases in length and reorganizes to occupy the total volume of the capsid. The structure goes from 3D hexagonal to 2D hexagonal, cholesteric and isotropic, following the sequence reported for solutions of short DNA fragments [5]. After partial ejection of DNA, multivalent cations (polyamines) were added to the solution. Ions diffuse freely through the protein capsid and induce the collapse of each individual DNA chain (3000 to 55000 bp i.e. 1.4-18 μ m long) inside each capsid. Toroidal DNA structures are formed. We show how the frustration arising between chirality and hexagonal packing combined with the strong curvature imposed by the small volume of the capsid impose phasing of the helices and variations the DNA helical pitch [6].

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Frontiers in European Research on Liquid Crystalline Soft Matter

LC Lab Bandol, France, May 27-29th 2009



Session i: Liquid crystals in and from living matter and in medicine



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Liquid-Crystallization of Ultrashort DNA and RNA Oligomers: a Phase Behavior Rich in Challenges for Soft-Matter Science

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Ultrashort complementary DNA and RNA oligomers, down to 6 base pairs in length, are found to exhibit nematic and columnar liquid crystal (LC) phases, even though such fragments of double helices lack the shape anisotropy required for liquid crystal orientational ordering. These phases are produced by the end-to-end adhesion and consequent living polymerization of the duplexes into polydisperse anisotropic rod-shaped aggregates, which can order.

The phase behavior of concentrated solutions of ultrashort DNA and RNA oligomers appears to be very rich and rooted in various basic mechanisms of self-organization of soft matter

Mixtures of single- and double-stranded oligomers phase separate. LC droplets rich in duplexes nucleate and coexist with an isotropic solution rich in unpaired single strands. This phase separation, that we find also in mixtures of DNA duplexes and PEG, can be understood as resulting from the combination of duplex adhesion and depletion-type forces favoring the segregation of rigid duplexes from flexible chains.

Quite surprisingly, this new form of spontaneous partitioning of complementary DNA extends to solutions of oligonucleotides with various degrees of randomness in their sequences. As an extreme example, we have found LC-isotropic phase separation in solutions of 20meric DNA with totally random sequence. These behavior results in an intriguing randomness-length phase diagram yet to be understood.

Another interesting topic emerges from studying the handedness of the chiral nematic N* phase, easily accessible since it often lays within the visible range. Quite remarkably, the handedness of the N* helix is not always the same, but rather it depends on the terminals of the oligomeric duplexes.

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Session i: Liquid crystals in and from living matter and in medicine



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Unsolved problems in liquid crystal defects and textures, with examples from both synthetic matter and biological systems

There are numerous unsolved paradoxes in liquid crystals and also many plausible experiments which do not work, even after repeated tentatives and high level of sophistication. Traditionally negative results are never published. However, discussion of negative results can be extremely interesting in certain cases.

One example is that of thick and thin threads, observed in normal or slightly twisted nematics. These threads often form loops which decrease in diameter and disappear, or give rise to a singular point. The initial topological situations differ in such cases and considerations about energy also deserve attention.

The threads often recombine and if, for instance, threads AB and CD join at a point J which is singular and unstable, two new threads form which are either AC and BD or AD and BC, or a third situation, A,B,C,D being four fixed points. The problem is to know the initial topological situation corresponding to a well-defined type of recombination. This type of problem is also encountered in the study of blue phases with highly complex structures found between the isotropic and the cholesteric phase.

The problem of recombination is also interesting to consider in the study of chromosomes, in bacteria and in some flagellates, which show a cholesteric structure, and there are plausible analogies with the well known process of crossing-over in many types of chromosomes.

Similar examples can be discussed with smectics A and C, chiral or not, and also in the case of cholesteric phases of diverse biopolymers, collagen for instance.

I will end by some examples on a much larger scale, that of the whole individual, the embryo for instance, with a collagen network just below the future epidermis, with remarkable singularities and geometries closely related to those of disclinations and screw dislocations in cholesterics. The discussion of such structures leads to reconsider the question of curvilinear transformations of morphology introduced by D'Arcy Thompson in 1917 in his famous book *On Growth and Form*. This research field was not fully appreciated by many biologists, since their attempts to give clear drawings of these transformations on concrete examples were unsuccessful, and as usual they did not publish such work. However, the ideas of D'Arcy Thompson have been revived in many recent articles on the morphometry of diverse species, and we believe that the examination of the singularities will be unavoidable in order to have a coherent view of such transformations, either in the study of development, or at the level of biological evolution.

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Session i. Liquid crystals in and from living matter and in medicine



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Nanodisks and Nuclisomes

–from model membranes to targeted drug delivery

In order to increase the basic knowledge and understanding of biological membranes access to simple, yet accurate, model systems is important. Model membranes that faithfully reflect the structure and properties of biological membranes are essential also for studies of, e.g., the structure/function of membrane proteins and drug-membrane interactions. Commonly employed model membranes include surfactant micelles, supported lipid mono- and bilayers, and liposomes. The latter have due to their versatility and the straightforward means for preparation found many important applications. The closed structure and inherent instability of conventional liposomes constitute, however, a potential problem for certain applications. We have discovered and developed a novel type of nanosized bilayer disks that avoid these problems. Initial investigations suggest that the disks constitute an interesting alternative to liposomes as model membranes in partition and interaction studies. We believe, furthermore, that the PEG-stabilized disks may prove valuable for formulation and transport of peptide-, genetic, as well as hydrophobic/amphiphilic drugs.

The efficacy of conventional cancer chemotherapy is often limited by severe side effects that preclude therapeutic drug levels from being reached at the tumour site. Targeted drug delivery via liposomes attempts to minimize the dose-limiting side effects by encapsulating the cytotoxic agent in liposomes and attaching tumour-specific ligands to the liposome surface. However, despite some progress the strategy with targeted liposomes loaded with conventional anticancer drugs has so far only had limited success in the treatment of cancer. In a collaborative project we have for some years been exploring a novel concept for targeted cancer therapy. The concept, which utilizes liposomal carriers in combination with a double targeting principle, aims at the delivery of Auger-emitting radionuclides to the nucleus of tumour cells. Targeting liposomes are loaded with a radionuclide-labelled DNA-intercalating compound, to specifically transport liposomes to tumour cells in a first step and to deliver radionuclides into DNA in a second. We call our nuclide filled liposomes Nuclisome[®]-particles and are currently evaluating their potential in a number of cell and animal models.

Frontiers in European Research on Liquid Crystalline Soft Matter

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Session ii. Drops, bubbles, tubes, foams and films



Pearl drops

While drops on solids usually form kinds of lenses, there are a few situations where they can remain quasi-spherical. We describe different tricks to generate such liquid pearls (texturing or heating solid substrates, texturing liquid surfaces). Then we focus on a few dynamical situations: the absence of contact line dramatically affects these situations, by minimizing the effect of viscosity, there again contrasting with observations or more "common" drops.

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Frontiers in European Research on Liquid Crystalline Soft Matter

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Session ii: Drops, bubbles, tubes, foams and films



Liquids in one and two dimensions

Thin free standing liquid crystal films and filaments represent unique objects of soft matter. They are fascinating not only from an aesthetic point of view, due to their lightness and colorfulness. Everyone of us has encountered such films, and played with them, already in early childhood, in the form of soap films, soap bubbles and foams. They play an important role in many biological and technological processes.

Early scientific studies of static and dynamic properties of such free standing films originate from 19. century. They are connected with the names of Joseph Plateau, Athanase Dupré and Lord Rayleigh, among others. We present recent experiments that investigate thin films of smectic and lyotropic liquids. The oscillations of thin liquid filaments and of bubbles, and rupture dynamics of films are studied. The experiments provide insight into processes of self organization of colloids in two dimensions, the dynamics of rupture and the aging of foams.

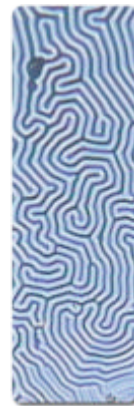
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Session ii. Drops, bubbles, tubes, foams and films



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Collective rotations on surfaces, stable boolaamphiphiles monolayers overcoming collapse, incorporation of large objects into LC lyotropic phases, motion of ions in LC: an overview of my recent LC works

I will give a brief overview of the LC research done in my experimental group. The first problem discussed will concern monolayers of boolaamphiphiles which overcome monolayer collapse upon compression. Next I will discuss the collective rotations of LC ferroelectric monolayer on water with typical rotation times of the order of minutes. I will also show how to speed up 1000-fold the phase separation process in LC/polymer mixtures using AC electric field of low frequency. Finally I will discuss some results concerning incorporation of carbon nanotubes into hexagonal phases of lyotropic liquid crystals.

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Session ii. Drops, bubbles, tubes, foams and films

Shear Induced Formation of Multi-Lamellar Vesicles (“Onions”)

Many surfactant lamellar phases form multi-lamellar vesicles, often called “onions” when subjected to shear flow, the reason for which still is not well understood. More recent experiments have demonstrated that transitions between the planar lamellar state (lower shear rates) and the state of onions (higher shear rates) are reversible and that they represent true history independent steady states. Also the steady state onion size varies with the applied shear rate in a reversible way. Focusing on the binary water-C10E₃ (triethyleneglycol decyl ether) we present the steady state shear diagram and follow the structural transitions using time resolved rheo-SANS, rheo-SALS and rheo-NMR.



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Session ii: Drops, bubbles, tubes, foams and films



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The Formation of Square Lamellae by Self-Assembled Symmetric Single-Chain Bolaamphiphiles

The self-assembly of the symmetric single-chain polymethylene-1, ω -bis(phospho-cholines) (PC-Cn-PC) with chain lengths from 22 up to 32 carbon atoms and two polar phosphocholine headgroups is exclusively driven by hydrophobic interactions of the long alkyl chains. This process leads to the formation of a dense network of helical nanofibers [1]. In contrast, the single-chain bolaamphiphiles tetra- and hexa-triacontane-1, ω -diyl-bis[2-(dimethylammonio)-ethylphosphate] (Me₂PE-Cn-Me₂PE, n = 34, 36) and the partly deuterated analogue (Me₂PE-C11-(CD₂)₁₂-C11-Me₂PE) self-assemble in water to square lamellae, a new type of amphiphilic aggregates with up to now unknown geometrical shape. In a first step, the self-assembly of these long-chain bolaamphiphiles leads to the formation of a dense network of nanofibers with strong gelling properties. Within one day, the nanofibers transform into square lamellae that grow up to an edge length of about 100 nm. The nanofibers are linked to one or two (opposite) corners of the squares in a kite-shaped way. After one week, all fibers have been transformed into square lamellae getting stacked in a gel cake. Within several weeks, a compact cake is formed by syneresis. The nanofiber-to-square lamella-transformation process as well as the underlying changes of the packing pattern were investigated by differential scanning calorimetry (DSC), Fourier transform infrared (FT-IR), transmission electron microscopy (TEM), small angle neutron scattering (SANS), and X-ray scattering.

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Frontiers in European Research on Liquid Crystalline Soft Matter

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Session iii. Colloidal liquid crystals and liquid crystal colloids



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Nematic Colloidal Crystals, Superstructures and Optical Microresonators

Dispersions of particles in liquid crystals show several novel classes of anisotropic forces between inclusions, which result in an amazing diversity of assembled patterns, such as linear chains [1] and 2D colloidal crystals of microspheres [2]. The forces between the particles in nematic colloids are extremely strong, anisotropic and long-range. This leads to a broad variety of colloidal assemblies in liquid crystals, which cannot be observed in isotropic solvents: colloidal wires, assembled by entangled topological defects [3], superstructures in the mixtures of large and small colloidal particles [4] and a broad variety of 2D nematic colloidal crystals. In all cases, the colloidal binding energy is several orders of magnitude stronger compared to water based colloids. The mechanisms of self-assembly in nematic colloids are discussed, showing this is a novel paradigm in colloidal science, which can lead to new approaches to colloidal self-assembly for photonic devices. Tunable optical microresonators, based on whispering gallery modes in nematic droplets are presented.

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Session iii. Colloidal liquid crystals and liquid crystal colloids

Self-organized nanocomposites: carbon nanotubes ordered by liquid crystals



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Organizing nanoparticles is a current challenge of fundamental and technological importance. Among nanoparticles carbon nanotubes (CNTs) have attracted great attention because of their extremely anisotropic shape, making them the existing objects closest to one-dimensionality, but especially due to their exceptional electrical, mechanical and thermal properties¹. These appealing aspects have as counterpart a difficulty in manipulation due to the nanotube tendency to bundle resulting into disorganized aggregates that prevent the transfer into the macroscopic world of the properties of isolated nanotubes. Liquid crystals, thanks to their self-organization constitute a route for ordering CNTs via a transfer of their unidirectional alignment onto CNTs dispersed in them². The mechanisms behind the alignment appear not straightforward and have been recently studied theoretically³.

In our work we have used non-functionalized CNTs and in the case of thermotropic hosts even the use of surfactants was avoided despite their possible aid in improving the dispersion. This choice was taken in order to avoid introducing unknown variables that could affect the properties of our system. As we can monitor directly the CNT behavior from their Raman response our system can be considered a model system for studying liquid crystalline based nanocomposites. We have demonstrated that liquid crystals can impose an alignment independently from the type of liquid crystalline host system⁴. This means that a liquid crystalline state has aligning effect *per se*. In fact, single-walled carbon nanotubes have been unidirectional aligned by thermotropic as well as by lyotropic liquid crystals. The specific molecular structure of the host enters into play in the dispersion and presumably in the aligning efficiency. Differences in the interaction between liquid crystal molecules of various structure and carbon nanotubes has been observed indicating a stronger effect in aromatic systems⁵. Ordering power is also affected by the nanotube concentration and interestingly alignment of carbon nanotubes could still be observed for relatively high carbon nanotube concentration, for which percolation is observed.

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Session iii. Colloidal liquid crystals and liquid crystal colloids



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Single wall carbon nanotubes: liquid crystal properties and nematic ordering in composites

Single wall carbon nanotubes (SWCNTs) display remarkable anisotropic mechanical, optical, conductivity properties among others. Exploiting these features at large scale, in composite materials, requires both a good dispersion of individual tubes and a control of their orientational order. A recent trend has been the use of liquid crystals to orient single-wall carbon nanotubes, by doping a liquid crystal matrix with SWCNTs. The direct formation of a nematic phase at large concentrations has been much less explored. We will discuss the specific problems arisen by such composites.

Using single-stranded DNA as a stabilizer in water renders possible the preparation of concentrated (above 1% wt.) dispersions of individualized SWCNTs. We have explored two main techniques to obtain anisotropic materials from such dispersions. First, a highly viscous nematic phase is observed at concentrations above 4% wt and can be processed to form SWCNTs films after drying. Second, the addition of a water-soluble polymer and subsequent water evaporation yields the formation of concentrated composite materials in which the tubes remain individualized, as shown by the persistence of photoluminescence properties. A controllable alignment in the films is then performed or reinforced by stretching.

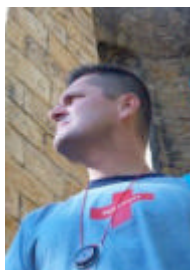
We will finally discuss the measurement of the nematic order parameter in such materials. Various methods are found in the literature to estimate roughly the orientational order from optical absorption, Raman or X-Ray scattering properties of carbon nanotubes, but some discrepancies are observed. We have proposed a method to compute it exactly from polarized Raman and photoluminescence scatterings. To test its accuracy, we have followed the polarization changes of the scattered intensity in progressively stretched polymer composites of increasing concentrations.

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Session iii: Colloidal liquid crystals and liquid crystal colloids



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Capillary rise of the interface between coexisting isotropic and nematic phases

We present an approximate theory for the shape of the interface between co-existing isotropic and nematic phases in contact with a solid vertical wall. In the weak-anchoring limit, the director field is rigid and uniform in the capillary rise region and we find that the capillary rise height depends non-trivially on the orientation of the director field relative to the solid-fluid interface. For strong surface anchoring the director field adjusts to the preferred homeotropic or planar anchoring at the solid-liquid and liquid-liquid interfaces. The shape of the interfacial profile is now a function of the balance between the surface energy and the splay and bend elastic deformation energies. Interestingly, for both weak and strong anchoring the profile decays non-monotonically albeit only very weakly so. We compare our theory with recent capillary rise experiments on co-existing isotropic and nematic phases of colloidal platelets [D. van der Beek *et al.*, *Phys. Rev. Lett.* 2006, **97**, 087801] and are able to extract from the experimental data the surface tension and the anchoring strength.

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Session iii: Colloidal liquid crystals and liquid crystal colloids



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Goethite: extraordinary mineral liquid crystals

Goethite (α -FeOOH) can be synthesized as boardlike crystalline nanorods (of typical dimensions 200 x 40 x 20 nm³ which can be varied over a wide range). These particles can be stabilized electrostatically in water of pH=3. Dispersions of these particles display the richest liquid crystal phase behaviour found in mineral liquid crystals, forming different nematic, columnar [1] and smectic [2] phases. We employed (microradian) small-angle x-ray diffraction at 2 different beamlines of the European Synchrotron Radiation Facility to investigate these different structures.

These mineral particles can be very polydisperse (above 50%), but alternative synthesis methods and repeated centrifugation steps can be used [3] to reduce their polydispersity to about 15%. We will discuss the important role sedimentation and fractionation play on the occurrence of the different LC phases for systems of different polydispersities [4]. In the special case that the width of the particles is the geometric mean of their length and thickness, we recently identified biaxial LC phases.

Finally, Goethite particles also show interesting magnetic properties. They possess a permanent magnetic moment along their long axis combined with an induced moment with an easy axis along the shortest particle dimension. This combination leads to an extreme sensitivity to magnetic fields and peculiar re-orientation phenomena when the strength of the external magnetic field is varied. We show this can even lead to magnetic-field induced phase transitions.

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Session iv. Liquid crystals for new functional materials, organic electronics and photovoltaics



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Complexity in Liquid Crystal Self Assembly

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We have recently introduced the concept of polyphilic molecular tectons to design new and complex types of organization in LC systems. [1] Among them, there are liquid crystalline honeycomb-like arrays of triangular, square, pentagonal and hexagonal cylinders, which were formed by self-assembly of ternary block molecules. More complex cylinder nets composed of cylinders with very different shape and having different materials in the interior of the cylinders were now achieved by using molecular tectons composed of four instead of only three incompatible segments (quaternary block molecules). These LC phases can be described by a multi-colour tiling of space. Among these new structures there is the liquid crystalline Kagome (a periodic packing combining hexagonal and triangular cylinders) [2] and numerous other multicolour tiling patterns. This work is part of the ESF supported collaborative EUROCORES (SONS II) project SCALES.

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LC Lab Bandol, France, May 27-29th 2009



Session iv. Liquid crystals for new functional materials, organic electronics and photovoltaics

Semiconducting nematic liquid crystals: properties and devices

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We have recently pioneered a liquid crystal approach to organic semiconductors, whereby thin, uniform films of light-emitting and charge-transporting nematics are formed as insoluble polymer networks by photopolymerisation using ultraviolet light. The orientational anisotropy of these materials allows polarized electroluminescence and the alignment direction is patternable using photoalignment techniques. A further advantage is that photolithography can be used to pixellate a full colour display. We demonstrate these properties [1], and show that the materials have very high order parameters and birefringence, greater than 0.9 in both cases [2].

We also discuss a liquid crystal composite approach to make photovoltaic devices [3]. Firstly an electron-donating, visible-light absorbing, nematic liquid crystal blend is used to form a nanogrooved surface with a large interface area to an overlying electron-accepting layer. This forms a bilayer photovoltaic device with a distributed interface to allow efficient separation and transport of the photogenerated electrons and holes. We show that nematic liquid crystals provide reasonably high charge carrier mobility and we discuss the performance of the photovoltaic devices.

Finally we report photoinduced surface gratings on these materials. We discuss the mechanism of their formation and possible applications.

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Session iv. Liquid crystals for new functional materials, organic electronics and photovoltaics

The perspectives of modelling and simulations for device and non-device applications of liquid crystals



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The physical properties of soft materials vary significantly with their phase organization and morphology [1] and thus a key aspect in the development of new materials of this kind rests on the possibility of controlling their molecular assemblage from the nano scale, e.g. for organic electronics applications [2], up to the much larger micro-scale, e.g. for photonic applications [3]. Corresponding to this range of length scales of interest the modelling and simulation problem has also to be tackled at different resolutions: atomistic, molecular and coarser grain lattice models. In this talk we plan to show some examples of each, highlighting the current state of the art and perspectives.

At atomistic level, we demonstrate the current possibilities of predicting the organization and properties of low molecular mass liquid crystals starting from their molecular structure and in particular the prediction of transition temperatures and observable properties (e.g. dielectric constant, NMR dipolar couplings) for nematic liquid crystals [4]. We also discuss the realistic prediction of Resonant Energy Transfer, in systems of interest for light harvesting devices [5].

At the molecular resolution level we show, in particular, structured organizations obtained from fullerene containing mesogens [6].

Finally, we discuss the possibility, first hinted in a seminal paper by Nelson [7] of using colloidal particles coated with a layer of nematic liquid crystals to build complex micro-scale architectures [7]. As shown in [7,8], trying to cover the sphere leads to four half-strength tetrahedrally placed topological defects, potentially suitable for a chemical attack yielding a tetravalent "colloidal atom". Using Monte Carlo simulations we show that the number and position of these valence spots can be varied by the application of suitable multipolar fields [8], leading to a potentially powerful approach to new meso-scale organizations.

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Session iv. Liquid crystals for new functional materials, organic electronics and photovoltaics

Going beyond the reflectance limit of cholesteric liquid crystals: experimental and theoretical investigations

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The reflectance of cholesteric liquid crystals (CLC) is limited to 50% of ambient (unpolarized) light at normal incidence because circularly polarized light of the same handedness than the helix is reflected.

We report the elaboration procedure and the structural properties of Polymer-Stabilized CLCs which reflect more than 50% in the infrared spectrum. Photopolymerizable mesogens are blended with a CLC exhibiting a thermally induced helicity inversion and the mixture is cured with UV-light when the helix is right-handed. The reflectance exceeds 50% when measured at the temperature assigned at a helicoidal structure with the same pitch but a lefthanded sense before curing. From SEM investigations, it is shown that the organization of the mesophase is transferred onto the structure of the polymer network and arced patterns are revealed in relation with the twisted plywood model given by Bouligand to describe the cholesteric arrangement of chitin molecules in the cuticle of arthropods. The gel structure is discussed as containing two populations of low molar mass LC molecules (free and polymer bound fractions). Each of them was characterized by a band of circularly polarized light which is selectively reflected.

The optical properties of the structure are investigated numerically by means of a one-dimensional finite-difference time-domain algorithm. Taking into consideration that the distribution of the domains occupied by the two populations cannot be described by a deterministic model, the overall optical behaviour of the structure is assessed by averaging the contribution of stochastically generated one-dimensional samples. Each sample is subdivided into a number of randomly interlaced polymer bound and free fractions with inverse helicoidal structures. The overall distribution of these regions is controlled by adjusting the percentage of the polymer to values that can be directly correlated with experimental data. The reflectance of each sample is calculated independently and the total reflection spectrum is derived by averaging over a sufficient number of samples. Results demonstrate that structures with randomly distributed areas of alternating senses of helicity are indeed capable of providing enhanced reflectance that exceeds the 50% limit.

Novel opportunities to modulate the reflection over the whole light flux range are offered. Potential applications are related to the light management for smart windows or hyperreflective polarizer-free displays with a larger scale of reflectivity levels.

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Session iv. Liquid crystals for new functional materials, organic electronics and photovoltaics

Electroclinic effect amplification, polydispersity and the stability of smectics

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The classical (and highly successful) approach to systematically tailor liquid crystal materials for specific applications is the formulation of optimised mixtures consisting of several mesogenic compounds and non-mesogenic additives such as chiral dopants or UV-stabilizers. While the design of nematic mixtures is highly developed and widely applied, far less is known about the mixing of smectics and the particular effects thereof.

We recently discovered that the electroclinic effect of a chiral smectic A (SmA*) material (consisting of a phenylpyrimidine host and a chiral dopant) was amplified by a factor of three after adding only 5% of another homologous phenylpyrimidine, the molecular length of which was about twice the length of the host molecules [1]. This remarkable electroclinic effect amplification stimulated a more general investigation of how the mixing of smectogens with different molecular length affects the stability, the molecular ordering, and the properties of smectics.

Considering the principle of close packing it seems that the nematic phase – due to the absence of long-range translational order – should be the ideal liquid crystal phase to accommodate molecular rods of different length whereas the periodic layer structure of smectic phases seems to be rather inappropriate for a close packing of rod-like molecules differing in length by, e. g. a factor of two. We thus investigated binary mixtures of several mesogenic phenylpyrimidine homologues (thus making the molecular length distribution in the mixtures extremely bimodal) and expected the smectic A (SmA) and smectic C (SmC) phases to be destabilized whereas the nematic phase should be stabilized (i. e., broadened in the x,T-phase diagrams). The actual results of these experiments are indeed completely reverse to the naive picture drawn above: Whereas the nematic phase (present in the pure homologues of shorter length) completely disappears after the addition of a few percent of the longer homologue, there is no indication of a destabilization of the smectic state at all, i. e., the smectic temperature range in the phase diagram is preserved or even broadened. In addition, the balance between non-tilted SmA and tilted SmC phases is shifted towards the non-tilted SmA. Even in the case where both components only possess SmC phases, SmA is the only liquid crystal phase found in the bimodal mixtures. In conclusion, the bimodal length distribution of smectogenic molecules favours the formation of non-tilted SmA phases on the expense of nematic or tilted SmC phases.

This quite counterintuitive result shades new light on our understanding of the stability of smectic order and will be discussed in terms of current theoretical models. It further opens pathways to a systematic design of interesting new materials such as de Vries-type smectics or low-tilt SmC materials. Finally, some relations to the phase behaviour of lyotropic-lamellar phases will be pointed out.

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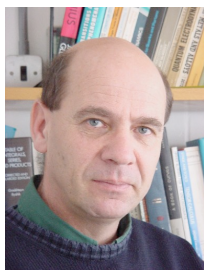
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Session v. Liquid crystals in sensors, actuators and novel optic and electrooptic devices

Switching an (improper) ferro-electric SmC* elastomer



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SmC* elastomers are the most complex and richest elastomers thus far synthesised. They can be made as large monodomain samples, free of textures and defects. They can be thought of having the physics of their underlying nematic elastomer order, with the smectic layer structure imposing additional rigid constraints for "strong" elastomers and not for "weak" elastomers.

I shall review the underlying thermal, mechanical and optical response of nematic elastomers. One can then discuss strong SmA and SmA* elastomers that already show subtle mechanical and electrical response, for instance 2-D rubber elasticity, mechanical Helfrich-Herault instabilities, and mechano-electro-clinic effects. With tilt in the C phase, there is the added complexity of shape change at low energy cost when the director rotates on the SmC cone about the layer normal.

SmC* elastomers couple to electrical, mechanical and optical (photo-isomerising) fields. They can therefore be switched in several ways - electrically to get mechanical response, mechanically to get optical and electrical response, optically to get mechanical and electrical response. I shall explore these responses, by first setting the scene with the large spontaneous mechanical shears induced by temperature or light when making the A-C transition.

The switching path depends on boundary conditions experienced by the elastomer. Typically textures develop as the director rotates by $\pm\Phi$. The textures rotate as the director advances, until when $\Phi=\pi$ the textures are lost to a switched monodomain structure.

In general the opto-mechanical response of SmC elastomers is poorly developed compared with experiment in SmC liquids and in nematic elastomers, and is a priority for the future.

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Polymer stabilised liquid crystals

Polymer stabilised liquid crystals are formed by uniformly dispersing bifunctional photoreactive monomers within a liquid crystal matrix and subsequently forming a polymer network within the liquid crystal phase through illumination with UV light. During the polymerisation process the forming polymer network phase separates from the liquid crystal and a bicontinuous structure is eventually formed.

The self-organised order of the liquid crystal is transferred onto the polymer network, which forms a structural template of the liquid crystal host in which it was formed. We will present several examples of such templating, from simple nematics, chiral superstructures and twist grain boundary structures to the morphology of topological defects. Polymer stabilisation can thus be used as an easy method to visualise liquid crystal director fields, in two- and with certain limitations also in three dimensions.

Polymer stabilisation of liquid crystals offers promising applications for example in the fields of reflective displays (electronic paper), heat repelling and automatically switchable windows for homes and greenhouses, the formation of photonic structures, or the mechanical improvement of fast switching ferroelectric devices. Using polymer stabilised ferroelectric liquid crystals (PSFLCs) we employed a rigorous experimental routine, together with a novel Landau description of PSFLCs to quantitatively determine the interaction between a polymer network and its liquid crystal matrix. We show that this interaction increases linearly with increasing polymer content, and comprises about 10-15% of the total potential of the liquid crystal at maximum. This implies that the preferential electro-optic properties of ferroelectric liquid crystals are not significantly compromised for the benefit of mechanical stabilisation. This will be demonstrated explicitly through electro-optic experiments.

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Session v. Liquid crystals in sensors, actuators and novel optic and electrooptic devices



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On the balance between ferroelectric and antiferroelectric order; mono-, bi-, and tristable liquid crystals

The surface-stabilized ferroelectric liquid crystal (SSFLC), known since 1980, is a bistable structure as it has two different stable states, with macroscopic electric polarization UP and DOWN, in absence of any applied electric field. The macroscopic polarization and bi-stability are results of the broken symmetry (from D_{∞} to C_2) brought about by the surface-induced suppression of the helix of the chiral smectic C^* phase. An appreciable variety of commercial devices have been developed based on these properties, for instance in the area of displays and optical processing. In both cases the very high speed of switching between the two symmetric states has been an additional asset. On the other hand, monostable antiferroelectric liquid crystals (AFLC), known since 1989, provide almost as fast electro-optic switching as the ferroelectrics, but in addition have some important advantages like analog grey scale and easy dc-compensated electronic addressing.

While nematic liquid crystals, characterized only by long-range orientational order, are relatively easy to align by treated cell surfaces, FLCs and AFLCs, which in addition have polar order as well as long-range translational order, are much more difficult to align. For instance, the anticlinic and antipolar structure of AFLCs is incompatible with any known surface condition.

By symmetry, a surface is more or less polar – and the surface states corresponding to the polarization to point into or out from the cell surface are not degenerate. When this polar anchoring is strong we can obtain monostable (twisted) structures with analog switching instead of bi-stable smectic C^* structures with binary switching. Moreover, in the AFLC case, the surfaces shift the balance between ferroelectric and antiferroelectric order as the surface promotes synclinic, polar order instead of the anticlinic antipolar order of the AFLC. In thin cells, the antiferroelectric smectic C_a^* phase can be completely squeezed out by the surfaces in favor of the ferroelectric (smectic C^*) state.

We demonstrate how control of surface polarity, rubbing directions, cell thickness, and liquid crystal material properties can lead to mono-, bi-, and even tri-stable liquid crystals. In the latter case we aim to use orthoconic materials, which provide extremely high contrast together with superior viewing angle, and tune the cell parameters to make the antiferroelectric ground state and the two field-induced ferroelectric states have essentially the same energy, i.e. a structure that has three stable states in absence of an applied electric field. This new structure has an interesting application potential as it combines some of the most important properties of ferroelectric and antiferroelectric liquid crystals.

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Electro-optic effects in reduced symmetry liquid crystals

The electro-optic properties of liquid crystals are at the heart of the displays industry, and everyone in the field is well aware of the desire to switch faster, with lower energy costs. This talk considers two distinct liquid crystalline systems, both with reduced symmetry; firstly the ferroelectric and antiferroelectric phases (also known as the intermediate phases), and secondly thermotropic biaxial liquid crystals. We describe some novel electro-optic effects observed in the intermediate phases, including field-induced phase transitions and asymmetric switching,. Techniques including resonant x-ray scattering and time-resolved x-ray scattering have been used to fully characterise the switching phenomena. The second part of the talk considers a biaxial nematic system. The controversy around the existence of biaxial nematic phases remains, but we have reported clear evidence of biaxial order in a bent-core material, and show marked differences in the electro-optic properties in the uniaxial and biaxial nematic regimes of this material. The results are discussed in the context of the potential for displays.

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