Centre for Liquid Crystal Research
Bangalore

तरल क्रिस्ट्ल अनुसंधान केंद्र
बेंगलुर

Annual Report
2007-2008

वार्षिक रिपोर्ट
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CENTRE FOR LIQUID CRYSTAL RESEARCH
BANGALORE

ANNUAL REPORT
2007 – 2008

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Chairman, EM Unit
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Former Vice-Chancellor
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FOREWORD

FOREWORD

The Centre for Liquid Crystal Research (CLCR) is under the administrative control of the Department of Science and Technology (DST), Ministry of Science and Technology. DST has been providing core support to the Centre in the form of a grant-in-aid for conducting basic and applied research in liquid crystals and related areas.

This Annual Report for the year 2007-2008, contains highlights of the research, development and academic programmes of the Centre, and lists the scientific output of the Centre in terms of academic activities and publications for the period from 1 April 2007 to 31 March 2008. The Centre has many sponsored projects from SERC (DST) and CSIR in India as well as through some collaborative/bilateral programmes with U.S.A., Japan, U.K., Italy, Bulgaria and Hungary.

The Centre has acquired two major equipments during this year: (i) Fluorescence laser scanning confocal microscope for liquid crystal director configuration studies under electric and magnetic fields. (ii) High spatial resolution x-ray diffractometer with fast detector for fine structural and kinetics of phase transition studies. These should add a new impetus to the research being carried out at the Centre.

A Research Advisory Board has been constituted with Prof. N.Kumar as Chairman to advice on the research activities being carried out at the Centre.

Nowadays, liquid crystal research has transformed into a truly interdisciplinary area. Earlier, the emphasis in the subject was on thermotropic liquid crystals in which physics, chemistry and engineering each played a major role. Presently, the trend is towards lyotropic liquid crystals many of which mimic some biological systems. *The Centre plans to give a major thrust to these interdisciplinary areas (including biology) under the umbrella of soft matter.*

Bangalore
5 September 2008

K. A. SURESH
DIRECTOR

INTRODUCTION

The Centre for Liquid Crystal Research (CLCR) was earlier functioning as a Scientific Society registered under the Karnataka Societies Act. It was funded by an ad-hoc grant from the Department of Science and Technology, Government of India, project grants from SERC and from the funds made available by the Raman Research Institute Trust. The Centre was taken over in 1995 by the Govt. of India, and converted to an autonomous institution under the administrative control of the Department of Information Technology. Since December 2002 (effective April 2003), the Centre has come under the administrative control of the Department of Science and Technology, Ministry of Science and Technology. The objective of the Centre is to focus on basic science, and to develop a bias towards technology, in line with the international trends on liquid crystal materials, related areas and devices.

Today CLCR has equipped itself with state of the art equipment and facilities, and has carried out research and development on the synthesis and characterization of a host of liquid crystal materials. CLCR is the only centre in the country exclusively devoted to research and development in liquid crystals and related areas.

CLCR has also entered into an MOU to provide technical advice and characterization services to Bharat Electronics Ltd., a premier industrial organization under the Ministry of Defence manufacturing segment type liquid crystal display devices for various customer- specific applications.

Core funded project

The Department of Information Technology, Govt. of India, in its proposal submitted to the Planning Commission provided for CLCR, an outlay of Rs.12.88 crores for the 10th plan period. The grant was received by CLCR from the Department of Information & Technology for the year 2002-03. In December 2002, the Centre came under the administrative control of the Department of Science & Technology, Ministry of Science & Technology. From 2004 onwards, the grants shown below were received by CLCR from the Department of Science & Technology. Year wise break up of outlay proposed as per the XI Plan document, and approved is given in the table.

(Rs. in Lakhs)

Eleventh Plan Outlay	2007-08	2008-09	2009-10	2010-11	2011-12	Total
Proposed & approved Outlay	284.00 (FE 84.00)	415.00 (FE 179.00)	373.00 (FE 111.00)	442.00 (FE 151.00)	586.00 (FE 262.00)	2100.00 (FE 797.00)

During the year 2007-08, a grant of Rs.4 Crores has been released by DST.

Reservation and Official Language

The Centre follows the national policy on reservation and official language as per rules and orders issued by the Government of India from time to time.

Sponsored projects

1. A three year Department of Science & Technology – SERC (2004-05) Project on "Photo induced effect in liquid crystals" costing Rs.12.94 lakhs was sanctioned in November 2004 and the work is in progress. [S.Krishna Prasad, Geetha G.Nair and D.S.Shankar Rao].

2. A three year project entitled “Investigations of the photo-stimulated phenomena in liquid crystals” between CLCR, Bangalore and Instituto Nazionale di Fisica della Materia (INFM), Italy was selected by the Department of Science & Technology as a joint research project within the framework of the Indo-Italian Program of Cooperation in Science & Technology 2005-07 in August 2005. A grant of Rs.1.18 lakhs being the first year’s allocation was received during the year 2006-07. [Indian side: S.Krishna Prasad, Geetha G.Nair and D.S.Shankar Rao; Italian side: Domenico Paparo, Enrico Santamato, Giancarlo Abbate, Lorenzo Marrucci]

3. A three year Council of Scientific and Industrial Research – CSIR Project # 1931 on “Molecular design to stabilize biaxial nematic and smectic A phases: synthesis of low molar mass non-conventional liquid crystals” has been sanctioned from 1 January 2005. The project costing Rs.8.12 lakhs came to an end in February 2008. [C.V.Yelamaggad, S.Krishna Prasad and Geetha G.Nair].

4. An Indo-Bulgarian research project proposal entitled “Investigations on flexoelectric properties of liquid crystals” (with C. V. Yelamaggad as the PI, and K.S.Krishnamurthy and S.Krishna Prasad as Co-PIs, from CLCR) was submitted to the DST during December 2006. K.S.Krishnamurthy made a presentation at the PAC meeting held at New Delhi during Feb. 2007 and the project has been sanctioned in February 2008 costing Rs.4.98 lakhs.

5. A three year Council of Scientific and Industrial Research – CSIR Project # 2162 on “Synthesis and liquid crystal behavior of chiral disc-rod oligomers” has been sanctioned from 1 March 2008. A grant of Rs.6.25 lakhs being the first

year's allocation has been sanctioned and the work is in progress. [C.V.Yelamaggad, S.Krishna Prasad and D.S.Shankar Rao].

6. A three year Department of Science & Technology – SERC (CVY1) Project on “Synthesis and characterization of Tris(N-salicylideneaniline) [TSAN]-based disc-shaped liquid crystals” costing Rs.33.16 lakhs was sanctioned in November 2007 and first instalment of grant of Rs.20 lakhs was received in January 2008 and the work is in progress.

RESEARCH ADVISORY BOARD

A Research Advisory Board was formed to advice on the research activities being carried out at the Centre.

1.	Prof. N. Kumar Raman Research Institute	Chairman
2.	Prof. Chandan Das Gupta Indian Institute of Science	Member
3.	Prof. S.Ramakrishnan Indian Institute of Science	Member
4.	Prof. Namita Surolia Jawaharlal Nehru Centre for Advanced Scientific Research	Member
5.	Prof. G.U.Kulkarni Jawaharlal Nehru Centre for Advanced Scientific Research	Member
6.	Dr. Ajit T. Kalghatgi Central Research Laboratory, Bharat Electronics Limited	Member
7.	Prof. K.A.Suresh Centre for Liquid Crystal Research	Convener

FINANCE COMMITTEE

A Finance Committee was constituted during the year with the following members.

1.	Joint Secretary & Financial Advisor, DST	Chairman
2.	Director, CLCR	Member
3.	Prof. K.V.Ramanathan, Indian Institute of Science, Bangalore	Member
4.	Dr. T.G.Ramesh, National Aerospace Laboratories, Bangalore	Member
5.	Administrative Officer, CLCR	Invitee

This Committee shall be reconstituted by the Council after a period of every 5 years.

RESEARCH AND DEVELOPMENTAL ACTIVITIES

NOVEL DISCOTIC LIQUID CRYSTAL – DNA COMPLEX FILMS AT INTERFACES

Disk-shaped liquid crystal (DLC) molecules are promising materials for organic electronics. Compared to conventional DLCs ionic DLCs are more interesting due to the presence ions as charge carriers. This also provides scope for studying electrostatic interactions with charged biological molecules like DNA. We have studied the films of a novel ionic DLC molecule, pyridinium salt tethered with hexaalkoxytriphenylene (PyTp) and DNA complex at air-water and air-solid interfaces. The PyTp monolayer was formed on the aqueous subphase containing small amount of DNA. The ionic interaction between PyTp and DNA molecules results in a PyTp-DNA complex monolayer. Surface manometry and Brewster angle microscope studies indicate the molecules to be in the edge-on configuration. With increase in pressure, the monolayer undergoes a transition from a loosely packed monolayer phase to a compactly packed monolayer phase. The PyTp-DNA complex films on silicon wafers were prepared using Langmuir-Blodgett (LB) technique. We find that several tens of layers of PyTp-DNA complex monolayer can be transferred with good efficiency. Atomic force microscope (AFM) images confirm the formation of a stable PyTp-DNA complex and its successful transfer on a substrate up to 50 layers. Fourier transform infrared spectroscopy studies on these LB films showed that DNA molecules maintained a B-form conformation. In addition to their scientific interest, the ability of the PyTp-DNA complex to form multilayers on a substrate by the LB technique has potential application in the fabrication of devices such as thin film transistors and nucleic acid-based biosensors.

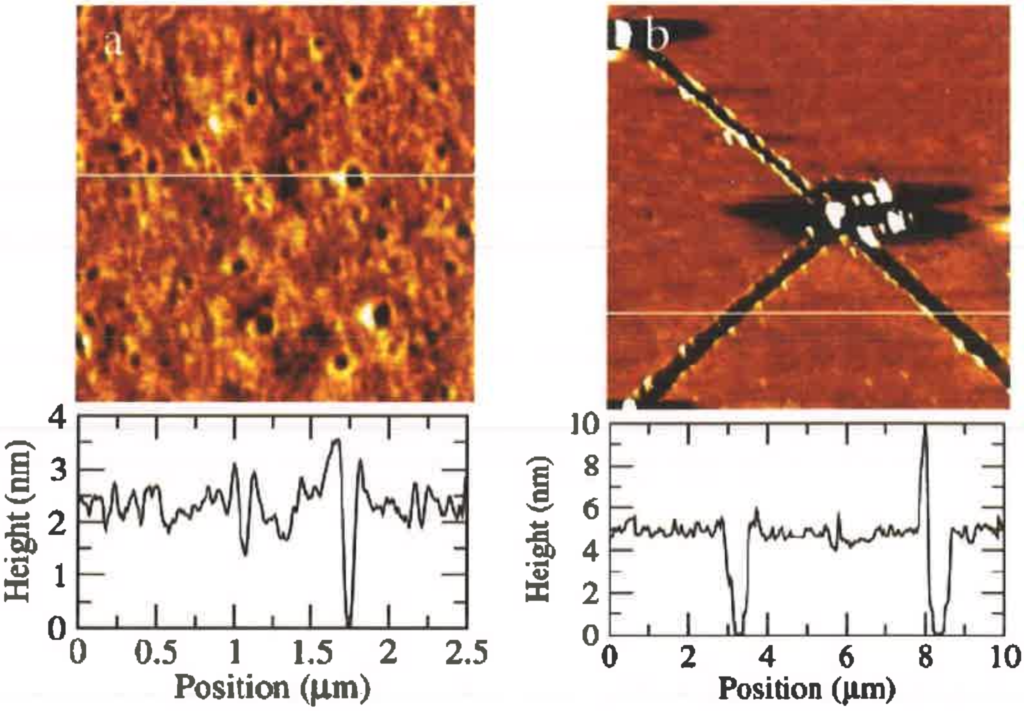


Figure : AFM topography images for two layers of a PyTp-DNA complex film transferred at 35 mN/m onto hydrophobic silicon substrate. (a) Morphology of the film surface showing roughness. (b) Scratched film to measure the thickness. The respective height profiles corresponding to the white lines on the images are shown below.

Investigator : K. A. Suresh
Collaborators: Alpana Nayak, Sandeep Kumar and Santanu K. Pal, Raman Research Institute, Bangalore

CONDUCTIVITY OF LANGMUIR-BLODGETT FILMS OF A DISCOTIC LIQUID CRYSTAL – DNA COMPLEX BY CURRENT-SENSING ATOMIC FORCE MICROSCOPY

Electron transport studies on films of ionic disk-shaped liquid crystal (DLC) molecule and its complex with DNA are important from the point of view of their applications as advanced materials in organic electronics. We have studied the electrical conductivity in monolayer films of a novel ionic disk-shaped liquid crystal molecule, pyridinium tethered with hexaalkoxytriphenylene (PyTp) and its complex with DNA by current sensing atomic force microscope (CS-AFM). The pure PyTp and the PyTp-DNA complex monolayer films were first formed at air-water interface and then transferred onto conducting substrates by Langmuir-Blodgett (LB) technique to study the nanoscale electron transport through these films. The conductive tip of CS-AFM, the LB film and the metal substrate form a nanoscopic metal-LB film-metal (M-LB-M) junction. We have measured the current-voltage (I-V) characteristics for the M-LB-M junction using CS-AFM and have analyzed the data quantitatively. We find that the I-V curves fit well to the Fowler-Nordheim (FN) model suggesting electron tunneling to be a possible mechanism for electron transport in our system.

Investigator : K. A. Suresh
Collaborators: Alpana Nayak, Sandeep Kumar and Santanu K. Pal, Raman Research Institute, Bangalore

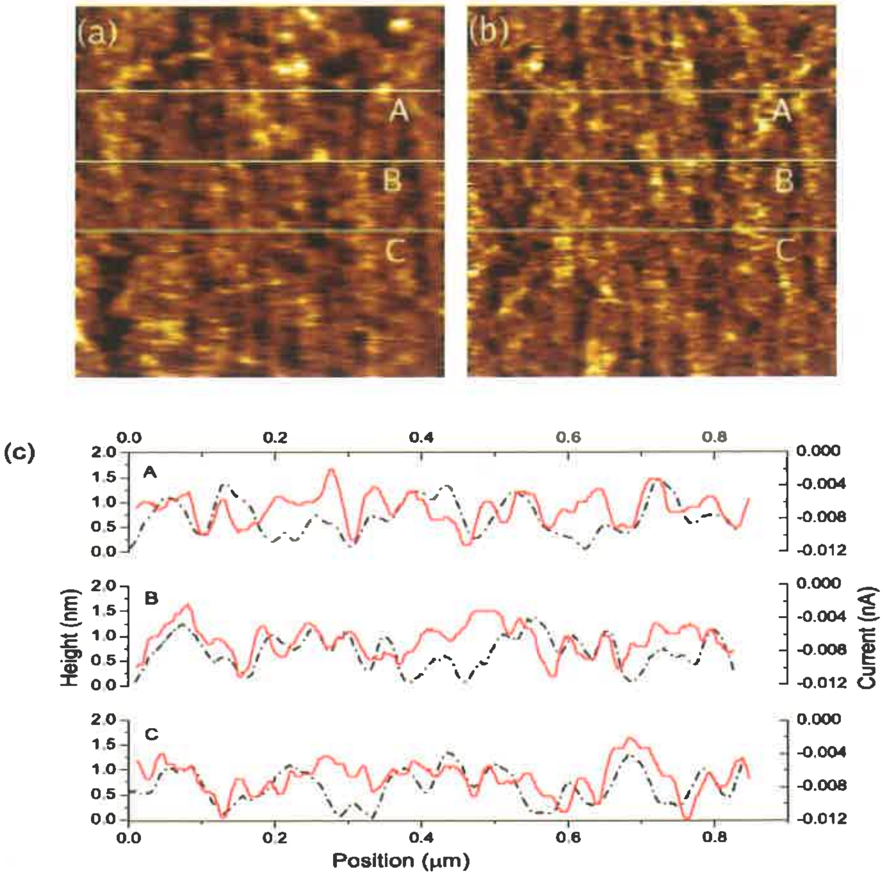
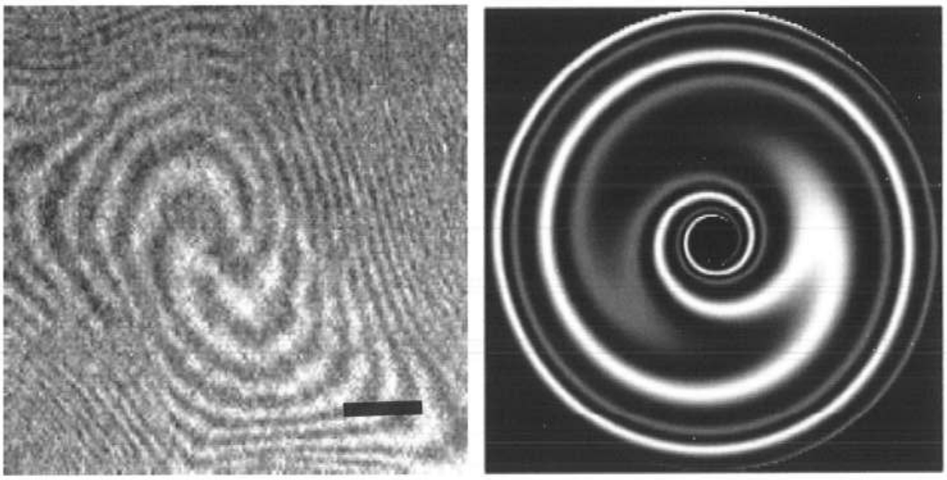


Figure : CS-AFM images for PyTp-DNA complex monolayer film on silicon substrate with a constant force of 6 nN and a sample bias of -7 V : (a) Topography image. (b) Current image. (c) The height (dash-dotted line) and current (solid line) profiles corresponding to the lines drawn at 3 different positions on the respective topographic and current images.

SPATIOTEMPORAL PATTERNS DUE TO COLLECTIVE PRECESSION OF MOLECULES IN A LANGMUIR MONOLAYER

Spatiotemporal patterns like spiral waves and concentric circular stripe waves are ubiquitous in nature, occurring in a wide range of physical, chemical and biological systems. Langmuir monolayers of chiral liquid crystals on the surface of water exhibit orientational waves with complex spatiotemporal patterns. Tabe and Yokoyama have reported a surprising new type of nonequilibrium spatiotemporal pattern formation in Langmuir monolayers of chiral liquid- crystal molecules. These patterns arise from a collective precession of the tilt orientation of the liquid- crystal molecules, driven by the evaporation of water through the monolayer. We have investigated the behavior of these orientational waves around topological defects in the liquid-crystal director. Through Brewster angle microscopy, we find spiral waves (vortex) in monolayers of cholesteric acid, and we have modeled the patterns in detail by solving the equation of motion with appropriate boundary conditions. We find a good agreement between the experimental observations and the theoretical predictions. Furthermore, we have demonstrated that the rotation of the spirals can be controlled by controlling the rate of evaporation. These precessing molecules studied here can be regarded as synthetic molecular motors. These motors are interesting because they can perform various biological and chemical activities.



(a) Experimental (b) Theoretical

Figure : The experimentally observed (left) and theoretically predicted (right) patterns for a single vortex surrounded by a domain wall (scale bar = 250 μm).

Investigator : K. A. Suresh
Collaborators: Raj Kumar Gupta and Sandeep Kumar, Raman Research Institute, Bangalore
Leena M.Lopatina, Robin L. Selinger and Jonathan V.Selinger, Liquid Crystal Institute, Kent State University, Kent, USA

ELECTRIC-FIELD ASSISTED ACCELERATION OF THE PHOTOSTIMULATED NEMATIC-ISOTROPIC TRANSITION

Photoisomerization is a molecular property in which selective photoexcitation of the molecules causes transformation between isomers that are structurally different. The property has been of tremendous practical implication, for instance, in dye molecules employed in optical data storage devices such as CDs, DVDs, etc. More recently they are being investigated as candidates for molecular devices, like molecular switches, motors, and electronic components. The combination of this property with the self-assembling nature of liquid crystalline systems possessing large birefringence values is valuable from both application and fundamental points of view, especially in photostimulated non-equilibrium phase transitions. We have described a novel method of an accelerated means of recovering the equilibrium from the photo-driven state. The employed guest-host system consists of the photoactive guest azobenzene and host nonphotoactive molecules exhibiting a nematic mesophase. By irradiating the sample with UV radiation the system is photo-driven from the equilibrium nematic phase to the isotropic phase via an isothermal phase transition. The recovery of the equilibrium phase takes place spontaneously, but is very slow. We have demonstrated that by application of an electric field the recovery occurs at least *two orders of magnitude faster* (see figure 1). Since the recovery time depends on the magnitude of the applied field, it provides a convenient tool to control the duration of the recovery, a feature useful in tailoring the value of birefringence in optical devices. The rapid recovery is associated with the faster reverse isomerization and also observed in the isotropic phase, and therefore is applicable to all systems connected with such isomerization processes.

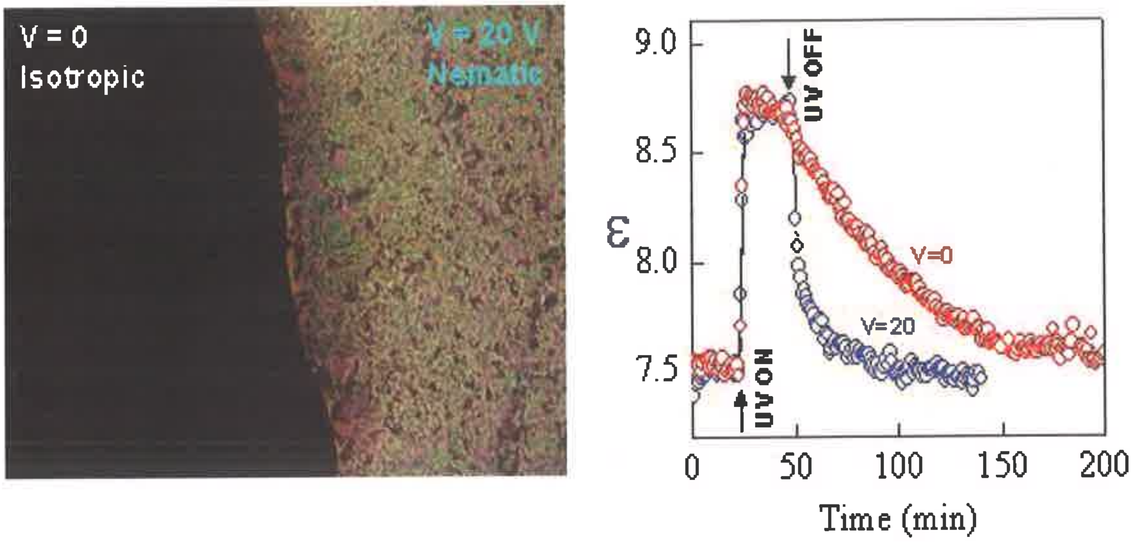


Figure 1: Pictorial and quantitative demonstration of electric-field assisted acceleration of thermal back relaxation

Investigators: S. Krishna Prasad, Geetha G. Nair and V.Jayalakshmi

EVIDENCE OF WORM-LIKE MICELLAR BEHAVIOUR IN CHROMONIC LIQUID CRYSTALS: XRAY AND DIELECTRIC STUDIES

Investigations on a novel class of lyotropic mesophases, referred to as chromonic liquid crystals (CLCs), have been attracting significant attention in recent years. Chromolyn, an anti-asthamatic drug, and perhaps the most extensively studied CLC lends its name to this class of materials. The novelty of CLCs arises due to several contrasting features that they exhibit, viz., (i) structurally these molecules do not consist of the aliphatic chain, an essential ingredient in the conventional lyotropic LCs (amphiphilic mesogens such as soaps and biological lipids), (ii) assembly-wise do not form micelles, which are the basic building blocks of lyotropic systems and (iii) the associated aggregation of the molecules show isodesmic behaviour as against the non-isodesmic behaviour of lyotropics. The interest in CLCs is also owing to their promising applications in antibiotics, anti-cancer agents and as aligning agents/compensating plates in the technologically important display devices. Apart from the medically important material mentioned above, certain dyes employed in the textile industry and a food colouring agent, Sunset Yellow FCF (SSY for short) have been investigated. We have performed Xray and dielectric investigations in the nematic (N) phase of a chromonic liquid crystalline system formed by aqueous solutions of SSY, in the absence and upon addition of salt. The results when viewed in conjunction with the rheological studies performed in our lab, can be summarized as follows. The Xray diffraction pattern obtained (figure 2(a)) in the N phase of the 20 mM salt +SSY mixture, as well as the pure SSY material exhibited a broad diffuse scattering at low angles along the equatorial direction and a sharp arc at wide angles along the meridional direction. Azimuthal angle scans taken indicate that the two reflections are at 90° with respect to each other, feature characteristic of the conventional N phase. The wide angle reflection corresponding to a spacing of 0.334 nm is due to the distance between the molecules arranged in a cofacial manner suggesting stacking of chromonic molecules in a columnar fashion

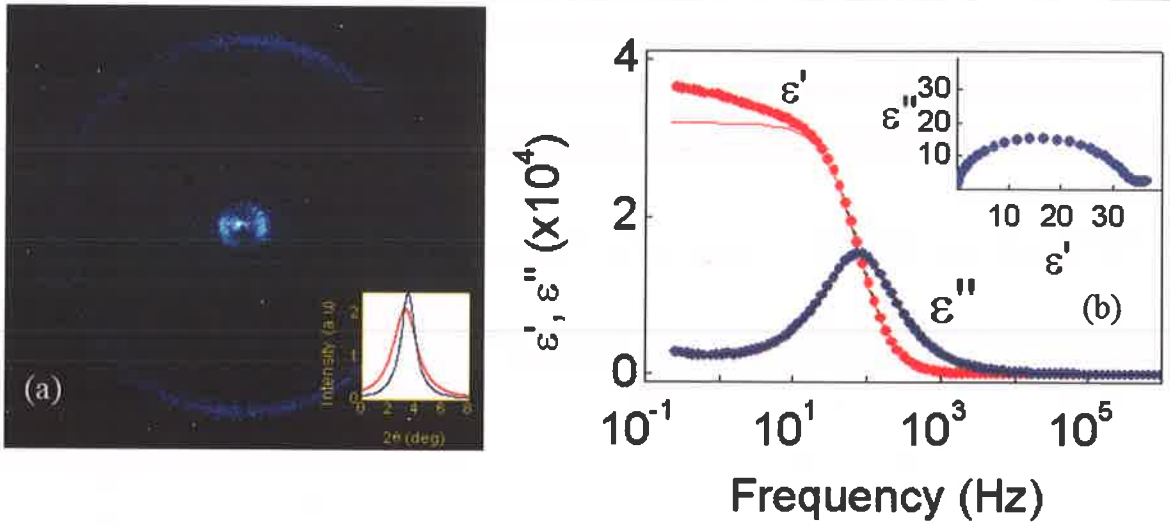


Figure 2: (a) Xray diffraction pattern and its intensity vs. Bragg angle profile in the N phase of the pure SSY material (red profile) and the salt mixture (blue profile). (b) Frequency spectrum of the real and imaginary parts of the dielectric constant.

with the intercolumnar interaction being restricted to only orientational order within the columnar stacks. With the addition of the salt, the distance between the stacks decreases, and the length over which the motion of the different columnar stacks are correlated, increases.

The dielectric measurements show a clear relaxation, which can be described by a Debye expression. Considering the geometry of the sample, the mode can be attributed to the relaxation of the director. The fact that the relaxation frequency (f_R) is quite low (70 Hz) corroborates the Xray result that the molecules are ordered in short columns and also the hydrogen bonding that takes place owing to the presence of the OH group in the structure. Addition of salt increases f_R, with the value doubling for the X_{salt}= 20 mM mixture (figure 2(b)). These data show that the neither the dimension of the aggregates nor the dynamics associated with them alter significantly with the addition of salt. Thus the primary influence of the salt would be on the microstructure due to the hydrogen bonding of the system and not on the individual aggregates.

Investigators: S. Krishna Prasad, Geetha G. Nair, Gurumurthy Hegde and V.Jayalakshmi

EFFECT OF CONFINEMENT ON PHOTO-INDUCED PHASE TRANSITIONS

Studies on liquid crystals confined in restricted geometries such as Anopore, Nucleopore (voids highly regular), aerogels (voids highly irregular) have been attracting significant attention of late. However studies involving photo-induced phase transitions in such restricted geometries are very few. This work constitutes the first experiments on the photo-isomerization driven isothermal phase transitions in liquid crystal-aerosil composites.

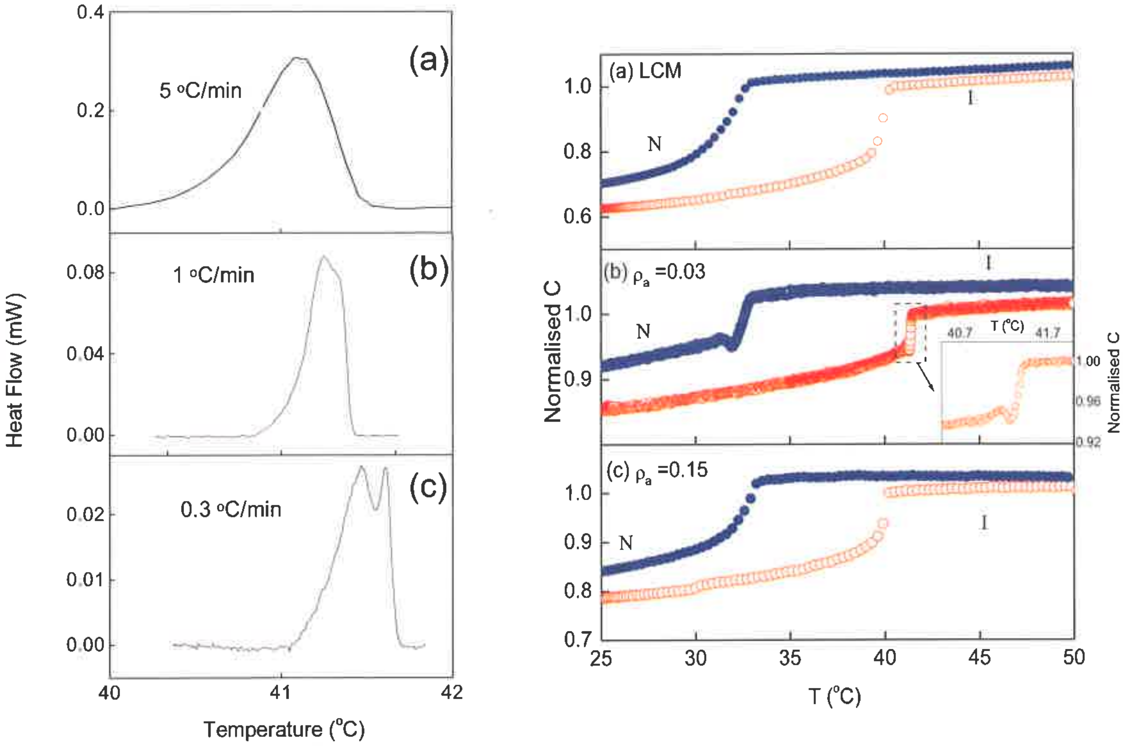


Figure: (Left) DSC scans for the mixture with Aerosil density 0.03 g cm^{-3} *composite obtained across the N-I transition. (Right) Temperature dependence of the normalized capacitance (C) for the (a) bulk and (b) 0.03 g cm*$^{-3}$*, (c) 0.15 g cm*$^{-3}$*aerosil composites. The N-I transition is signified by the step-like change.. The data for 0.03 g cm*$^{-3}$ *composite shows an additional peak (clearly seen in the inset) that is associated with a similar feature seen in the DSC scan for this composite. Solid blue circles- with UV. Open red circles -without UV.*

We have used a nematic liquid crystal (NLC-7CB) doped with an azobenzene dopant as a host and composites were prepared with varying compositions of aerosil. The photoisomerization process in azobenzene molecules is well known. When doped in liquid crystals the rod-like *E* form stabilizes the liquid crystallinity, and it is destabilized by the bent *Z* form when irradiated with UV. Therefore, the light driven *E-Z* change generally leads to a lowering of the phase transition temperature resulting in a photoinduced isothermal transition.

Differential scanning calorimetric (DSC) and dielectric spectroscopy techniques were used to characterize the nematic-isotropic (N-I)transition of the composites. The DSC scans taken at different cooling rates show that at slower rates, the bulk (mixture without aerosil) displays a single peak across the N-I transition, whereas a composite in the soft gel regime exhibits a double-peak profile. Such a double-peak profile, although seen in high resolution ac calorimetric studies has been observed for the first time in DSC experiments.

The studies carried out in the absence and presence of a UV radiation bring out interesting features such as (i) the photoinduced shift in the transition temperature is a non-monotonic function of the aerosil composition and appears qualitatively similar to the dependence of the transition temperature itself, and (ii) the thermal anomaly mentioned above characterizing the crossover is also seen in the temperature dependent as well as the temporal variation of the sample capacitance for the composite in the soft gel regime. We have also evaluated the different response times associated with the photochemical process as well as the thermal back relaxation process; the response times appear to have similar dependence on the aerosil concentration as the transition temperature.

Investigators: Geetha G. Nair, S. Krishna Prasad and V. Jayalakshmi

RHEOLOGICAL STUDIES OF CHROMONIC LIQUID CRYSTALS

Chromonic liquid crystals are lyotropic liquid crystals, but in general they do not possess a critical micelle concentration which is the case for the lyotropic liquid crystals formed by amphiphilic molecules. In the chromonic liquid crystal phase, generally an aqueous solution of a dye, drug, or nucleic acid assembles to form aggregates which are anisotropic in shape, rod-like or disc-like. If the concentration of these aggregates is high enough and if the shape of these aggregates is significantly anisotropic, a nematic liquid crystal phase, chromonic N, is formed. At higher concentrations and/or at lower temperatures, a second liquid crystal phase may appear in which the aggregates are also positionally ordered in a hexagonal array.

The interest in CLCs is due to their promising applications in antibiotics, anti-cancer agents and as aligning agents/compensating plates in the technologically important display devices.

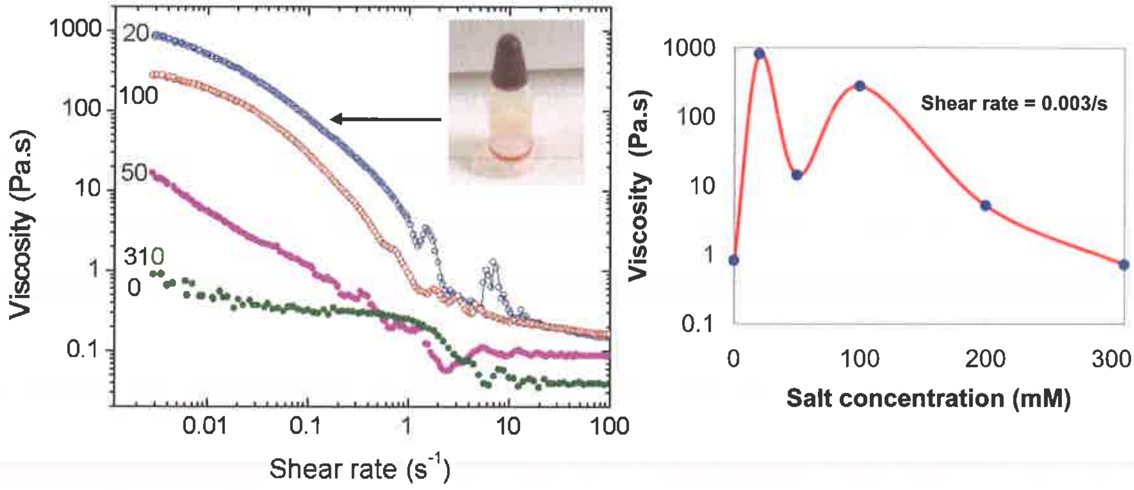


Figure: (Left) Influence of salt (Sodium Chloride) concentration on the steady state viscosity for a fixed value of Sunset Yellow (SSY) in the mixture. The number against each data set indicates the salt concentration in the mixture. All the materials exhibit shear thinning behaviour. Inset shows the 20 mM mixture in a vial kept upside down. Viscosity increases by nearly three orders of magnitude for this mixture. (Right) Salt concentration dependence of the apparent viscosity at very low shear rate (0.003 s-1) showing the three orders of magnitude increase in the value between the 20 mM mixture and the SSY material without salt. The profile of the non-monotonic variation seen is qualitatively similar to the behaviour in lyotropic systems exhibiting worm-like micelles.

Rheological investigations on a chromonic liquid crystalline system formed by aqueous solutions of a food coloring agent, Sunset Yellow (SSY), in the absence and upon addition of salt have been carried out. The salt concentration dependence of the steady state viscosity at low shear rates has a non-monotonic variation and qualitatively similar to the behaviour seen in worm-like micellar systems, a surprising result since chromonic systems are expected to be non-micellar in character. More interestingly for a particular low concentration of the salt (20 mM), the viscosity increases by three orders of magnitude in comparison with that of the pure chromonic material. The dynamic (oscillatory) rheological data bring out features which can be described in terms of a microstructure formation. Xray and dielectric studies were done to characterize the influence of salt on the aggregate structure of the Sunset Yellow molecules. Xray studies show that the stack spacing slightly decreases on addition of salt. Dielectric measurements indicate the H-bonding weakening on adding salt to SSY.

Investigators: Geetha G. Nair, S. Krishna Prasad and V. Jayalakshmi

ELECTRICALLY TUNABLE COLOR USING MIXTURES OF BENT-CORE AND ROD-SHAPE MOLECULES

We have studied several binary mixtures of the rod-shape compound (*4-n-octyloxyphenyl 4-n-hexyloxybenzoate*, one of the simplest liquid crystal material exhibiting nematic and tilted smectic (SmC) mesophases) and the bent-core material (*4-chloro-1,3-phenylene bis[4-(10-decenyloxy)benzoyloxy] benzoate* and *4,6-dichloro-1,3-phenylene-bis[4'-(9-decen-1-yloxy)-1,1'-biphenyl]4-carboxylate*, which forms nematic phase at relatively low temperatures). The careful measurements of phase diagrams of these mixtures showed that all mixtures have a nematic phase below the isotropic, and several of the mixtures show an induced smectic phase, i.e., anticlinic smectic A (SmC$_A$) phase below the nematic and several of them are stable at room temperature. X ray measurements were done to characterize these induced smectic phases.

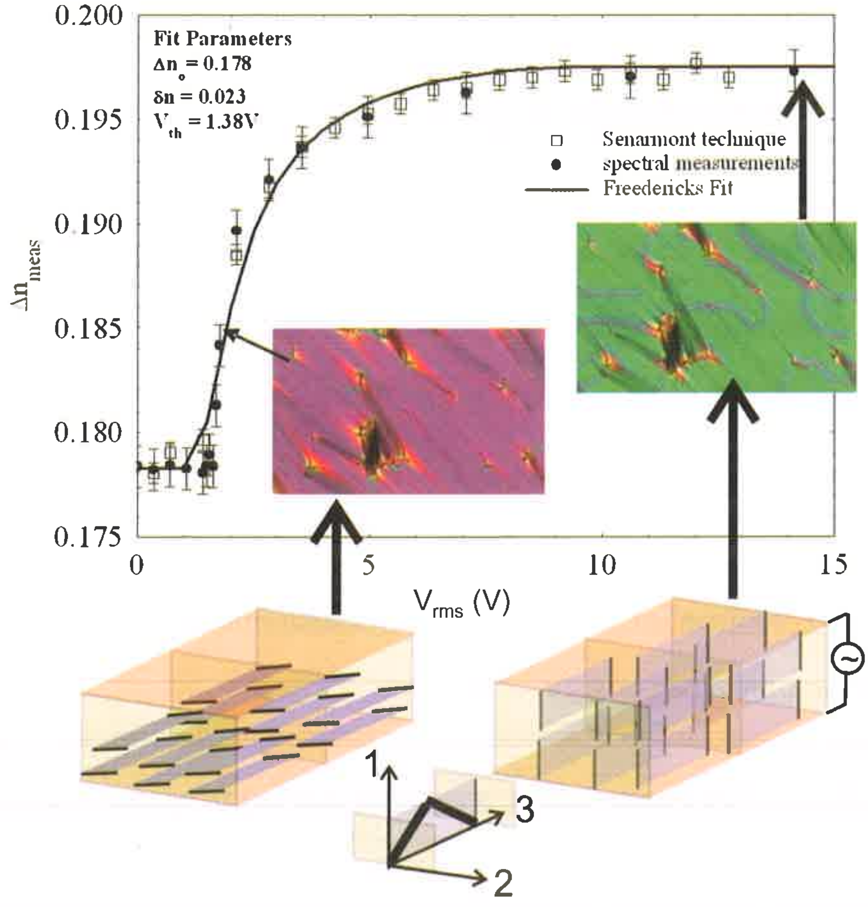


Figure: Voltage dependence of the effective birefringence measured for a mixture in the SmC_A *phase. The data are fitted assuming 2-D Freedericks-type switching of the second director, as illustrated in the lower part. Rectangles indicate the tilt-plane of the bent-core and rod-shape molecules. The local coordinate system 1, 2 and 3 is chosen so that 1 is parallel to the bend direction (second director) 3 is along the layer normal (main director), and 2 is perpendicular to 1 and 3.*

The electro-optical measurements show that the birefringence of the SmC$_A$ phase can be tuned by about 0.03 below 1V/µm fields without rotating the optical axis. Due to the smectic layer structure, the director can rotate only about the layer normal, which can be modeled as two dimensional rotation of the unit vector along the bend direction of the bent-core molecules analogous to two dimensional Freedericks transition.

Since the switching takes place by rotation about the layer normal, it is much faster than the rotation of the director in NLCs, and is not surprising that the measured rise time is below 0.1ms for 1V/µm fields, and the relaxation time is in the 1-4ms range even 50°C below the N-SmC_A transition. The fast switching speed in a wide temperature range with uniform alignment offers applications, such as in displays with black-and-white grey-scale, or in beam steering where the ordinary wave is varied to change the refraction angle and thus bend light away from the target.

Investigator : Geetha G. Nair
Collaborator: Antal Jakli, Liquid Crystal Institute, Kent State University, USA.

MESOMORPHIC BEHAVIOR OF BIVALENT CARBOHYDRATE AMPHIPHILES

Studies on neutral, non-ionic glycolipids assume significance due to their importance as one of the major constituents of cell membranes. Carbohydrate moieties in cell membranes play important role as adhesion points for protein binding, cell–cell interactions and various other interactions. Mesogenic properties of glycolipids arise due to amphiphilic character of the constituent molecules, possessing distinct hydrophilic and lyophilic segments. It is documented that open, acyclic sugar-appended alkyl glycosides exhibit columnar mesophase, whereas cyclic sugar-containing alkyl glycosides lead to layered structural arrangements in the mesophase. The driving force for the evolution of the mesophase is the phase segregation to form hydrophilic and hydrophobic microdomains.

Detailed polarizing optical microscopy, differential scanning calorimetry and X-ray diffraction experiments (see figure1) lead to the conclusion that the smectic A phase in this series of bivalent sugar amphiphiles is clearly different from the inverted glycolipids, reported in the literature, wherein the formation of discotic or columnar phases at lower temperatures and cubic phases at higher temperatures was observed. Different constitutional features of the inverted glycolipids and those of the bivalent sugar amphiphiles studied herein must be responsible for the different phase behavior in the two systems.

Another interesting outcome of these experiments is the observation that similar to compounds having a strongly polar terminal group, these materials have partial interdigitation of the molecules present in the bilayer structure, as determined from experimental d-spacing and computationally derived length of the molecules.

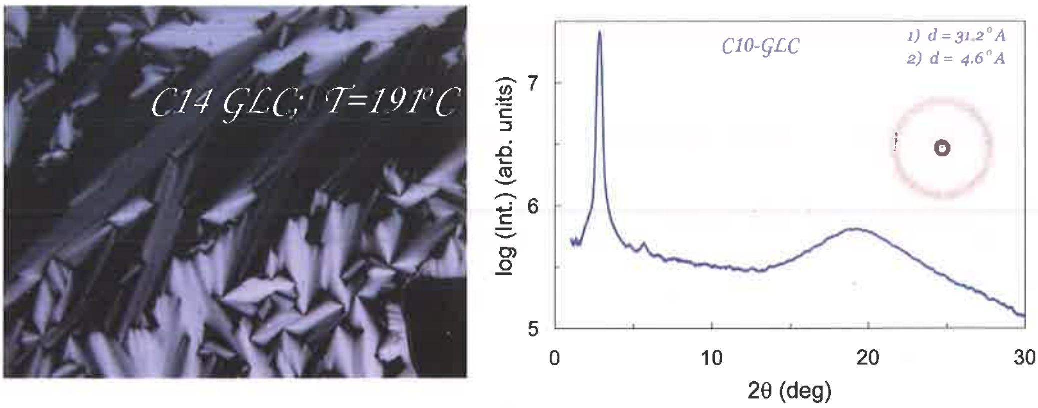


Figure 1: (a) Fan shaped texture of smectic A phase (b) Representative Xray diffraction pattern(inset), χ- averaged one dimensional intensity vs. 2θ profile in the smectic A phase.

<u>Investigators</u> : D.S Shankar Rao and S.Krishna Prasad
<u>Collaborator</u> : N.Jayaraman, Indian Institute of Science, Bangalore 560 012

MESOGENIC PROPERTIES OF NONPLANAR β-TETRABROMINATED TETRAALKYLOXY PORPHYRINS

Substituted porphyrins are growing in importance owing to their potential material applications and also for their unique physico-chemical properties, especially due to their extended large π-system, high thermal stability, diverse coordination and synthetic versatility. The choice of substituents group at the periphery of the porphyrin play vital role in altering the property to the macrocycle. Such porphyrins were employed in various materials applications such as molecular sensors, supramolecular network solids, catalytic chemistry and others. Our collaborators at the Indian Institute of Technology, Madras, have synthesized new nonplanar β-tetrabrominated tetralakyloxyporphyrins derivatives, which have been investigated for their mesomorphic properties by us employing optical microscopic and powder X-ray diffraction methods. The powder diffraction pattern for representative compound

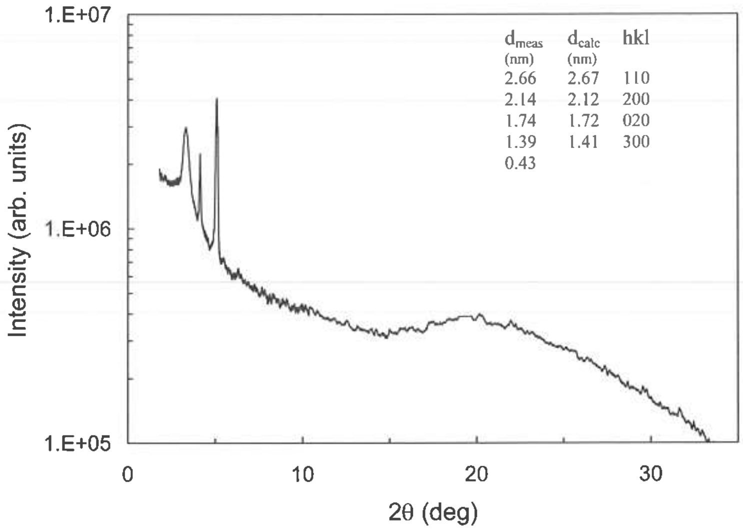


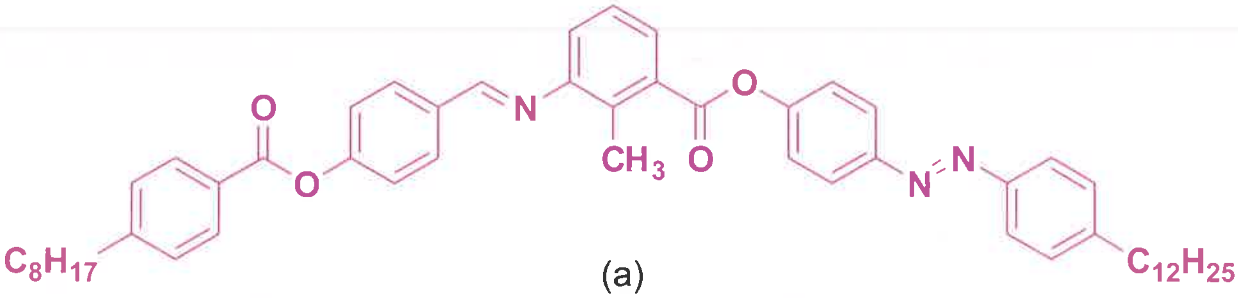
Figure 2: Low angle X-ray diffraction pattern of $CuT(4'-C_8P)PBr_4$ at 140°C. The inset shows the experimental and calculated d-spacings along with the corresponding hkl indices.

viz., CuT(4′-C_8P)PBr_4 is shown in Figure 2, and contains four sharp peaks in the low angle region (below $2\theta \sim 7^o$) followed by a diffuse maximum ($2\theta \sim 20^o$) in the wide angle region, the latter indicating the fluidity of the phase. The low angle peaks have been indexed to a 2-dimensional rectangular lattice with the lattice spacing a = 4.23 nm and b = 3.45 nm.

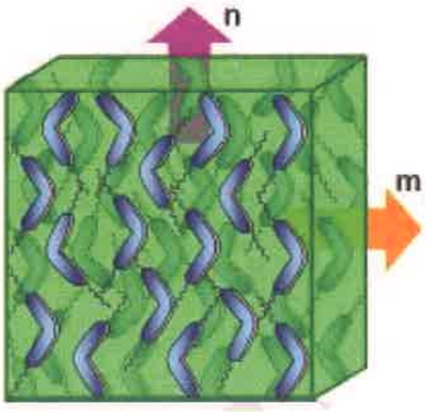
Investigators: D.S Shankar Rao and S.Krishna Prasad
Collaborator : P. Bhyrappa, Indian Institute of Technology Madras, Chennai 600 036.

BIAXIAL NEMATIC MATERIALS

As a Continuation of our work on the biaxial nematic materials, we synthesized A131, a biaxial nematic material discovered by us previously, on a large scale, and conducted a ^{13}C NMR study on this material and obtained very surprising and interesting results. We found that the conformation and ordering of the bent-shaped core significantly change between the uniaxial and biaxial nematic phases, with highest local nematic order not associated to the central ring in this azo substituted bent-core mesogen.



(a)



(b)

*Figure: (a) Molecular structure of A131 (b) Biaxial nematic phase with primary director **n** and secondary director **m**.*

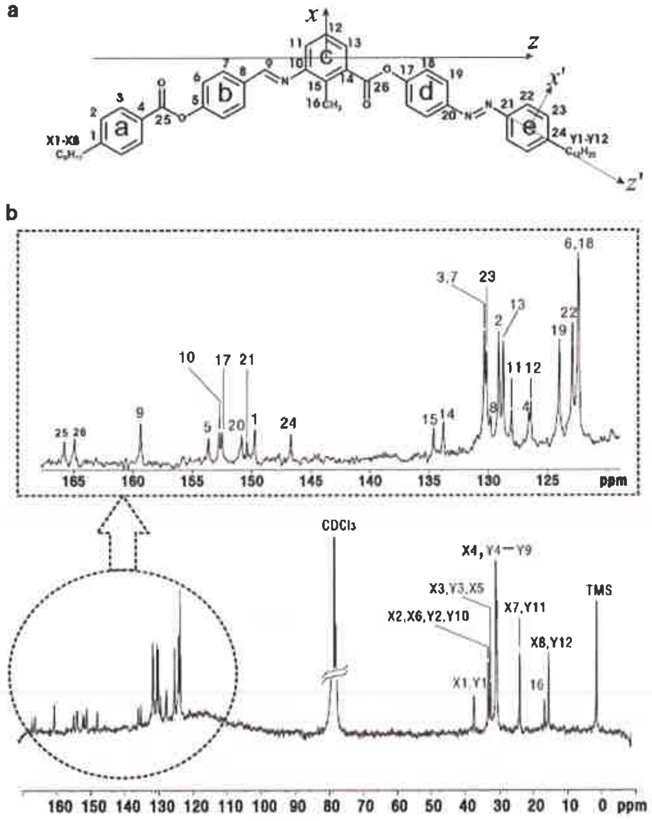


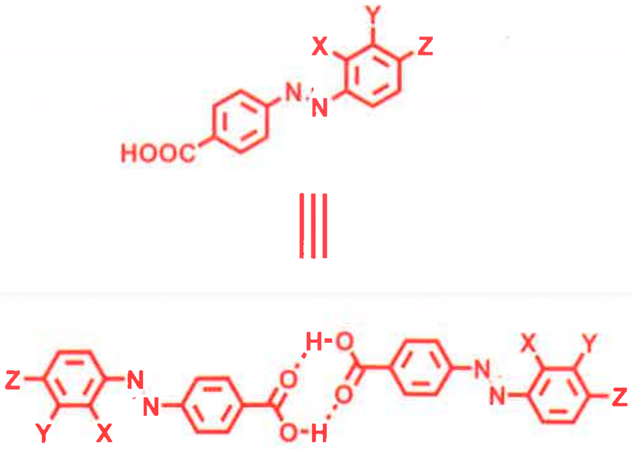
Figure: (a) a fragment coordinate system (x′, y′, z′), and a coordinate system (x, y, z) fixed on the central ring; (b) a typical high resolution ^{13}C NMR spectrum of A131 dissolved in $CDCl_3$ with ^{13}C assignments. Some peak assignments are shown in the inset of (b) for clarity.

Investigator : Veena Prasad

Collaborators: R.Y. Dong and J. Zhang, University of Manitoba, Canada
Satyendra Kumar, Kent State University, Kent, USA

MOLECULES TO MESOGENIC PHASMIDIC TYPE MATERIALS THROUGH INTER-MOLECULAR HYDROGEN BONDING

Two series of new azo molecules are synthesized and characterized. These molecules form dimers through inter-molecular hydrogen bonding, resulting in phasmidic type of compounds. This was once held to be a promising molecular architecture to form the biaxial nematic phases. We studied the mesomorphic properties of these new azo compounds using polarizing optical microscopy and differential scanning calorimetry. Investigations reveal that these compounds form a nematic, columnar and a highly ordered plastic type of mesophases. X- ray investigations of these mesophases are in progress to elucidate the exact nature of these mesophases. To the best of our knowledge, till today, only a handful of phasmidic type of mesogenic compounds are known, formed by the intermolecular hydrogen bonding.



$X = Y = Z = OC_nH_{2n+1}$ ----- Series 1
$X = H, Y = Z = OC_nH_{2n+1}$ ----- Series 2
n = 6, 8, 10, 12, 14, 16

Figure: Molecular structures of the phasmidic type of compounds synthesized.

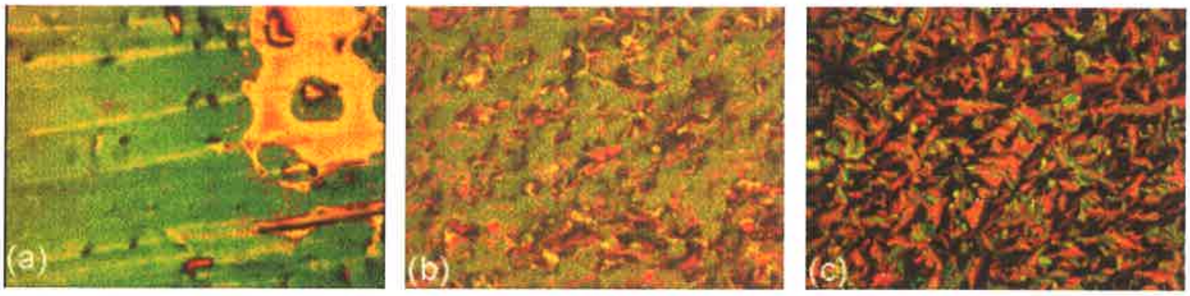
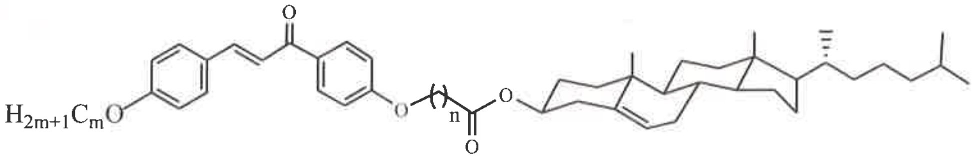


Figure: Textural photomicrographs of one of the compounds from series 1: On cooling from isotropic liquid (a) nematic , (b) nematic to columnar (c) columnar. (We could not get the homeotropic alignment for nematic phase even with surface treated glass plates)

Investigators : Veena Prasad and Sanjay K. Varshney
Collaborators: Satyendra Kumar and S-W. Kang, Kent State University, Kent, USA

FRUSTRATED LIQUID CRYSTALS: SYNTHESIS AND MESOMORPHIC BEHAVIOR OF NONSYMMETRICAL DIMERS POSSESSING CHIRAL AND SHORT BENT-CORE ENTITIES

Four series of dimers possessing pro-mesogenic cholesterol as a chiral moiety covalently linked to a fluorescent bent aromatic (chalcone) core through an oxyalkanoyloxy spacer of varying length and parity have been synthesized and characterized (Fig. 1). Within the homologous series, the dimers with even-parity spacer and short tail exhibit chiral nematic phase (N*) and blue phase (BP), where as the members with intermediate spacer length show the twist grain boundary (TGB) and / or smectic A (SmA) phase/s in addition. The thermal behavior of the higher members of these series depends on the length of the spacer. Similar trend was observed for lower and higher homologues of dimers possessing odd-parity spacer. Notably, the higher members of this series exhibit two twist grain boundary phases viz. TGBA (Fig. 2a) and TGBC* (Fig. 2b) consecutively occurring over a relatively wide thermal range with a new phase sequence. Thus, the occurrence of fluid frustrated phases, in particular, the blue phase in majority of the dimers indicate that chirality of these mesogens is high enough such that helical pitch of the chiral nematic phase is sufficiently short. The short bent-core chalcone entity in dimeric structure perhaps enhances their biaxiality and chirality.



Series I : **DC-3,m.** (m = 2 and 4-12)   Series III : **DC-5,m.** (m = 2 and 4-12)
Series II : **DC-4,m.** (m = 2 and 4-12)   Series IV : **DC-7,m.** (m = 2 and 4-12)
} n = 3, 4, 5 and 7

Figure 1: A general molecular structure of cholesterol-based dimers comprising short bent mesogenic core

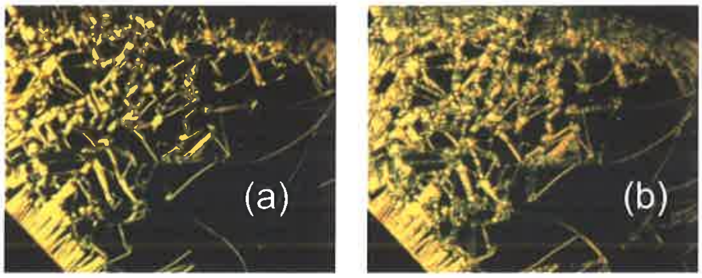


Figure 2: Microphotographs showing the transition from (a) straight filaments of TGB to (b) undulated filaments of TGBC phase observed for the dimer with oxypentanoyloxy spacer and n-dodecyloxy tail.*

Investigators: C.V.Yelamaggad, A.S.Achalkumar, D.S.Shankar Rao and S.Krishna Prasad

Collaborators: N.L.Bonde and A.K.Prajapati, M.S. University of Baroda, Vadodara.

MONODISPERSIVE LIQUID CRYSTAL PENTAMERS EXHIBITING UNUSUAL FLUID LAYERED PHASES

The synthesis of the first examples of multi-functional nonsymmetric (1a-b) and C_2 symmetric (2a-b) pentamers (Fig. 1) comprising five mesogenic segments interlinked through four flexible spacers varying in their length and parity is accomplished. Apart from devising synthetic feasibility, their physical properties have been improved by rendering them soluble in organic solvents and self-organizing to exhibit mesomorphism. The C_2 symmetric pentamers possess tolane, biphenyl and azobenzene cores, while nonsymmetrical ones contain cholesterol and naphthalene entities, additionally. These monodispersive supermolecules self-assemble into monolayered (Fig. 2e) or intercalated (Fig. 2f) phases, which appear to be rather new smectic modifications given the fact they possess unique textural pattern (Fig. 2a-d). Besides this, they possess electrochemical activity. Indubitably, this approach offers a unique way to designing multifunctional materials which can bridge the gap between low molar mass and polymeric LCs.

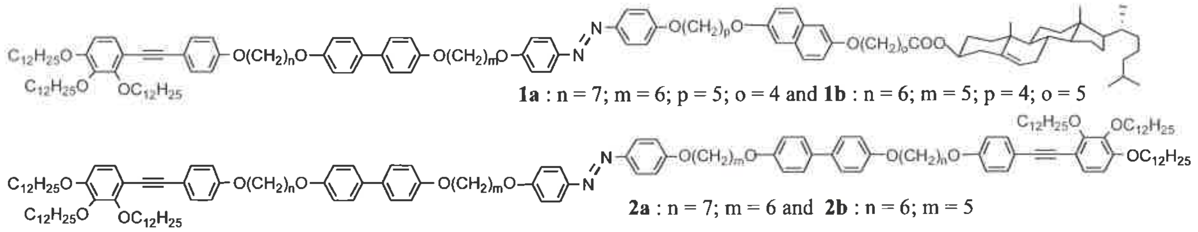


Figure 1: Molecular structure of nonsymmetric (1a-b) and C_2 symmetric (2a-b) pentamers composed of five anisometric moieties through four flexible spacers varying in their length and parity

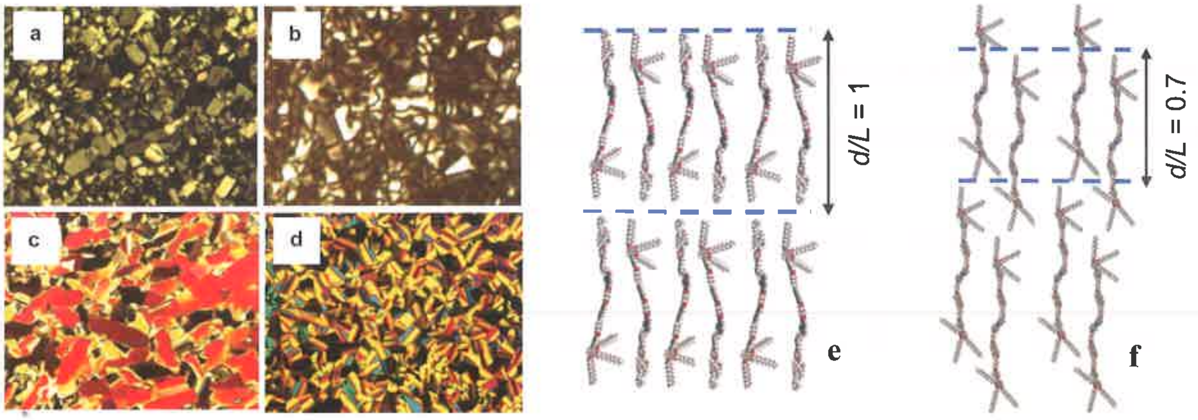
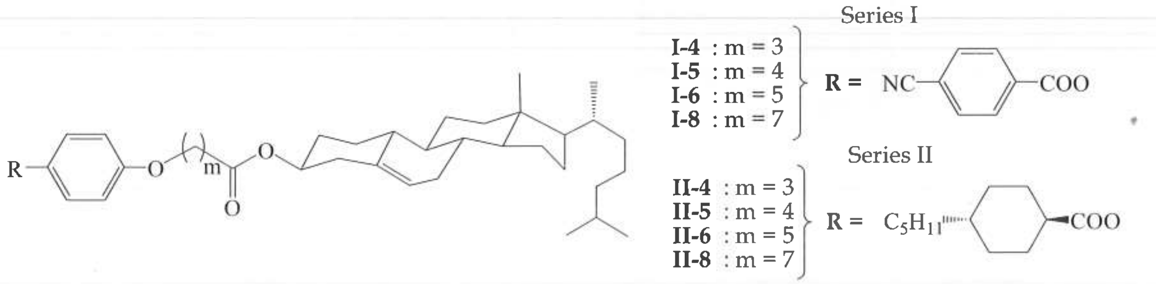


Figure 2. Microphotographs of the textures obtained for the smectic mesophases of pentamers: (a) and (b) monolayer smectic phase of 1a obtained during the slow and fast cooling; (c) intercalated smectic phase of 2a; (d) intercalated smectic phase of 2b. Also shown are the schematic representation of the self-assembly of pentamers 1b in a monolayered phase (e) and 2b in an intercalated layered phase (f).

Investigators: C.V.Yelamaggad, A. S. Achalkumar, D. S. Shankar Rao and S. Krishna Prasad

MESOMORPHIC CHIRAL NONSYMMETRICAL DIMERS: SYNTHESIS AND CHARACTERIZATION

Two types of nonsymmetric dimers formed by covalently linking cholesterol with either phenyl 4-cyanobenzoate (series I) or phenyl cyclohexanecarboxylate cores (series II) through a flexible spacer of varying length and parity have been synthesized and characterized. The dimers with terminal cyano group exhibit a polymesomorphic behavior; they display chiral nematic (N*), twist grain boundary (TGB) and smectic A (SmA) phases with an optional smectic C* (SmC*) phase. While cyclohexyl dimers stabilize N* with or without twist grain boundary phase (TGBC*) possessing the chiral smectic C blocks. The phase sequences and clearing temperatures of these set of dimers are dependant on the structure of the "second mesogen" attached to the cholesterol and spacer parity. UV-Vis and CD (Fig 2a-b) spectroscopy have been carried out in N* phase. An odd-even effect has been observed for the selective reflection wavelengths measured for both the series of dimers. To the best of our knowledge this is the first elaborative study on the chiroptical property of the chiral nematic phase formed by nonsymmetric chiral dimers. The present investigation could facilitate to further understanding of the structure-property relationships cholesterol-based nonsymmetric dimers.



(**n** denotes the total number of carbon atoms (m+1) in the spacer)

Figure 1: A general molecular structure of cholesterol-based dimers comprising two different mesogenic cores.

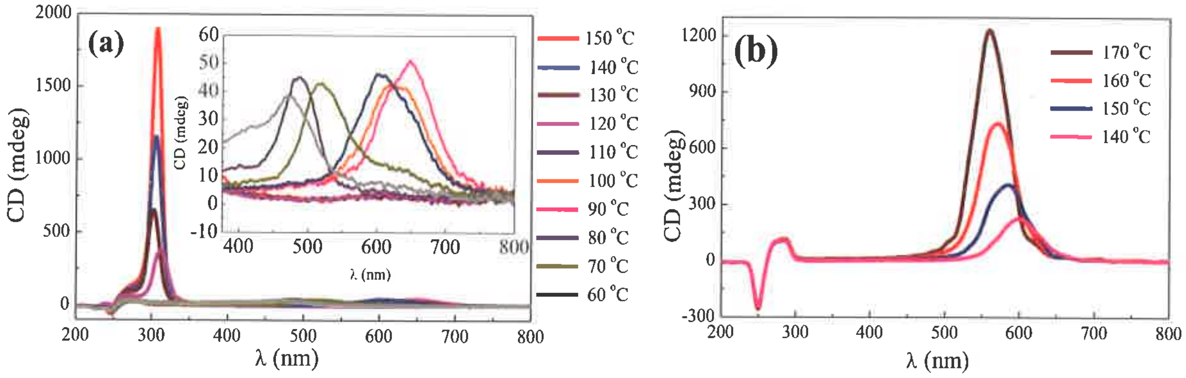
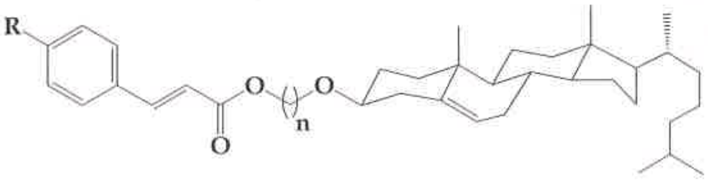


Figure 2: The temperature dependence of the CD spectra of the N phase recorded for the dimers comprising odd-parity (a) and even-parity (b) spacers.*

Investigators: C. V. Yelamaggad and G. Shanker.

NONSYMMETRIC CHOLESTEROL-BASED DIMERS COMPRISING SMALL SIZE ANISOMETRIC CORE

A new class of cholesterol-based nonsymmetric dimers having a short mesogenic core has been synthesized and characterized (Fig. 1). In particular, they comprise *O*-alkylated cinnamic acid and pro-mesogenic cholesterol segments interlinked covalently through a carbonyloxymethyleneoxy spacer of varying length and parity. The terminal chain of cinnamoyl core has also been varied to obtain four series of dimers (I to IV). The thermal properties of dimers are found to be critically dependent on the parity of the flexible spacer. The clearing temperature, as expected, depends on the parity of the space with odd-members possessing lower values (Fig. 2). Odd-parity dimers show chiral nematic (N*) and /or twist grain boundary (TGB) phase/s. On the other hand, the even-parity dimers are either crystalline or exhibit metastable N* and /or TGB phase/s with the exception of one compound for which two unknown mesophase have been observed. The odd-even effect was found to be indistinct for selective reflection wavelengths of the chiral nematic phase. For some dimers, a variation in the pitch of the chiral nematic phase as a function of temperature has been observed. The cyclic voltammetry experiments revealed the electrochemical property of a representative liquid crystal dimer.



I-5,12: n = 5; R = $OC_{12}H_{25}$
I-6,12: n = 6; R = $OC_{12}H_{25}$
I-7,12: n = 7; R = $OC_{12}H_{25}$
I-8,12: n = 8; R = $OC_{12}H_{25}$

II-5,16: n = 5; R = $OC_{16}H_{33}$
II-6,16: n = 6; R = $OC_{16}H_{33}$
II-7,16: n = 7; R = $OC_{16}H_{33}$
II-8,16: n = 8; R = $OC_{16}H_{33}$

III-5,18: n = 5; R = $OC_{18}H_{37}$
III-6,18: n = 6; R = $OC_{18}H_{37}$
III-7,18: n = 7; R = $OC_{18}H_{37}$
III-8,18: n = 8; R = $OC_{18}H_{37}$

IV-5, 22: n = 5; R = $OC_{22}H_{45}$
IV-6,22: n = 6; R = $OC_{22}H_{45}$
IV-7,22: n = 7; R = $OC_{22}H_{45}$
IV-8,22: n = 8; R = $OC_{22}H_{45}$

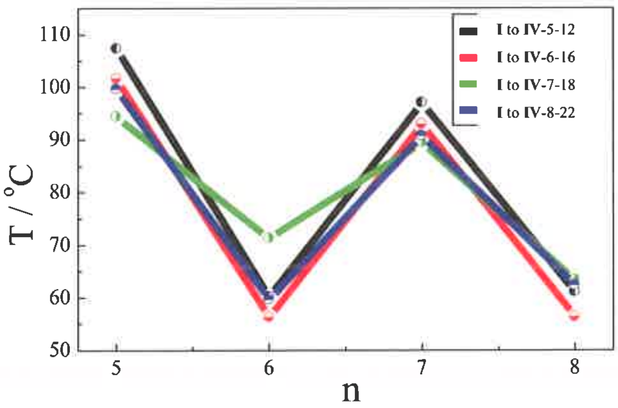
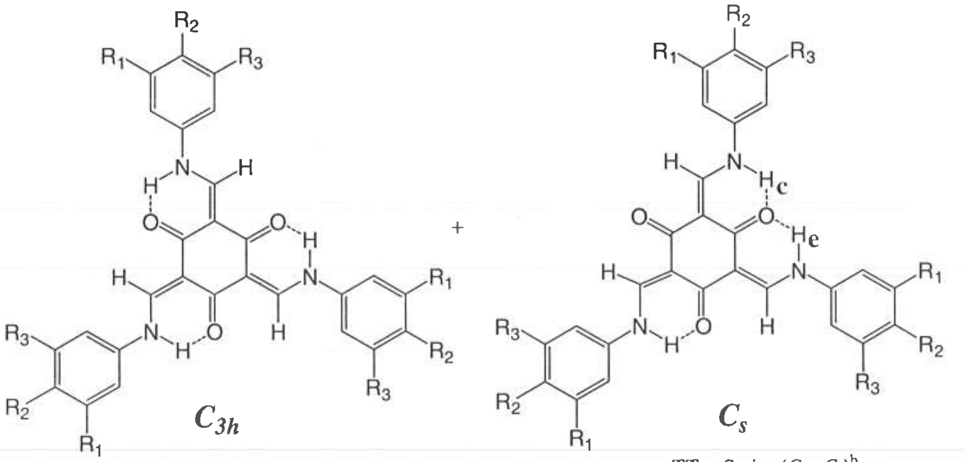


Figure 2: Dependence of the clearing / melting temperatures (T) of dimers, on the number of methylene units (n) in the alkylene spacer.

Investigators: C. V. Yelamaggad and G. Shanker.

ACHIRAL DISCOTIC MESOGENS DERIVED FROM DI- AND TRI-ALKOXY SUBSTITUTED TRIS(N-SALICYLIDENE-ANILINE)S EXISTING IN C_{3H} AND C_S KETO-ENAMINE FORMS: SYNTHESIS AND CHARACTERIZATION

Two series of discotics derived from tris(*N*-salicylidene-aniline)s [TSANs] (**DT-n** and **TT-n** series; Fig 1) in which the proton and the electron interact with each other through the H-bonding environment are accomplished. The synthesis is carried out by condensing 1,3,5-triformylphloroglucinol with the respective dialkoxyanilines or trialkoxyanilines. ^{1}H NMR and ^{1}H-^{1}H COSY NMR studies revealed their existence as an inseparable mixture of two keto-enamine tautomeric forms with C_{3h} and C_s rotational symmetries instead of the expected enol-imine form. The influence of the number of peripheral alkoxy tails on the columnar mesomorphic behavior is investigated using polarizing optical microscopy, differential scanning calorimetry and X-ray scattering. The fluid/glassy columnar states probed for a number of representative compounds confirmed the D_{6h} (hexagonal) or D_{2h} (rectangular) symmetry of the columns. The electronic absorption and emission characteristics of these compounds have been studied in both mesomorphic and solution states. Of special interest, the photoluminescence spectra of solution and fluid/glassy two-dimensional structure evidently disclose the promising light generating capability of these new discotics systems.



DT-n Series $(C_{3h}:C_s)^b$

DT-4 : $R_1 = R_2 = n\text{-}OC_4H_9$, $R_3 = H$ (1:1.99)
DT-5 : $R_1 = R_2 = n\text{-}OC_5H_{11}$, $R_3 = H$ (1:2.43)
DT-6 : $R_1 = R_2 = n\text{-}OC_6H_{13}$, $R_3 = H$ (1:2.47)
DT-7 : $R_1 = R_2 = n\text{-}OC_7H_{15}$, $R_3 = H$ (1:2.48)
DT-8 : $R_1 = R_2 = n\text{-}OC_8H_{17}$, $R_3 = H$ (1:1.8)
DT-10 : $R_1 = R_2 = n\text{-}OC_{10}H_{21}$, $R_3 = H$ (1:1.87)
DT-12 : $R_1 = R_2 = n\text{-}OC_{12}H_{25}$, $R_3 = H$ (1:2.21)
DT-16 : $R_1 = R_2 = n\text{-}OC_{16}H_{33}$, $R_3 = H$ (1:2.2)
DT-8B: $R_1 = R_2$ =3,7-Dimethyloctyloxy, $R_3 = H$ (1:1.3)

TT-n Series $(C_{3h}:C_s)^b$

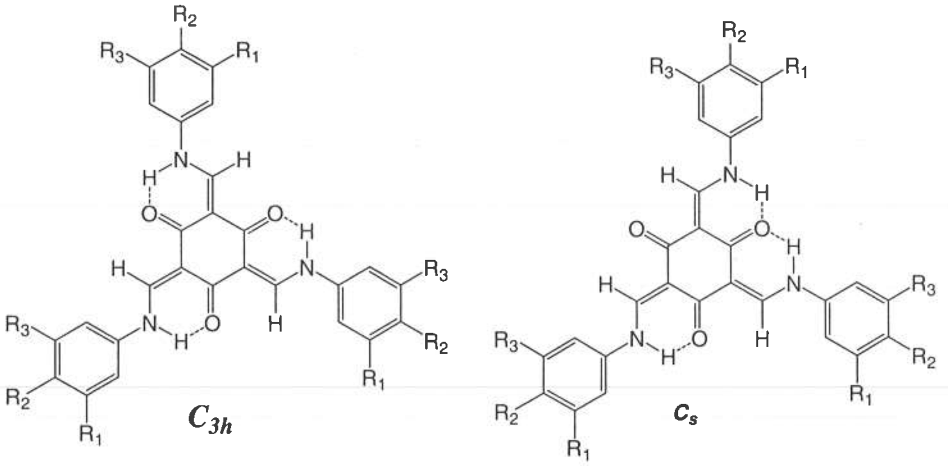
TT-4 : $R_1 = R_2 = R_3 = n\text{-}OC_4H_9$ (1:0.28)
TT-5 : $R_1 = R_2 = R_3 = n\text{-}OC_5H_{11}$ (1:1.07)
TT-6 : $R_1 = R_2 = R_3 = n\text{-}OC_6H_{13}$ (1:1.98)
TT-7 : $R_1 = R_2 = R_3 = n\text{-}OC_7H_{15}$ (1:2.97)
TT-8 : $R_1 = R_2 = R_3 = n\text{-}OC_8H_{17}$ (1:1.09)
TT-10 : $R_1 = R_2 = R_3 = n\text{-}OC_{10}H_{21}$ (1:1.08)
TT-12 : $R_1 = R_2 = R_3 = n\text{-}OC_{12}H_{25}$ (1:0.95)
TT-16 : $R_1 = R_2 = R_3 = n\text{-}OC_{16}H_{33}$ (1:1.23)
TT-8B: $R_1 = R_2 = R_3$ = 3,7-Dimethyloctyloxy (1:1.2)

Figure 1: A general molecular structure of two series of TSANs

Investigators: C.V.Yelamaggad, A. S. Achalkumar, D. S. Shankar Rao and S. Krishna Prasad

OPTICALLY ACTIVE TRIS(N-SALICYLIDENEANILINE)S: MANIFESTATION OF CHIRALITY FROM MOLECULES TO FLUID COLUMNAR PHASES

Tris(*N*-salicylideneaniline)s comprising chiral tails in varying numbers have been designed and synthesized (1, 2a, 2b and 2c: Fig. 1). These systems self-organize into room temperature helical columnar mesophase resulting from the chiral stacking of the constituent molecules differing in their rotational symmetry and constituent ratio as evidenced by optical, chiroptical, calorimetric and X-ray studies. The preferential rotation of the constituent shape-persistent C_{3h} and C_s keto-enamine tautomers enables the chirality present in the side-chains to be expressed into the helical conformation of the columns that is reflected by Cotton effects in the CD. Thus, another remarkable feature of TSANs is reported.



1 : $R_1 = R_2 =$ (3*S*)-3,7-Dimethyloctyloxy, $R_3 = H$
2a: $R_1 =$ (3*S*)-3,7-Dimethyloctyloxy, $R_2 = R_3 = n\text{-}OC_8H_{17}$
2b: $R_1 = R_2 =$ (3*S*)-3,7-Dimethyloctyloxy, $R_3 = n\text{-}OC_8H_{17}$
2c: $R_1 = R_2 = R_3 =$ (3*S*)-3,7-Dimethyloctyloxy

Figure 1: Molecular structure of optically active TSANs with peripheral chiral chains in varying numbers

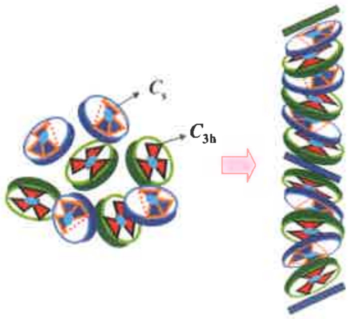


Figure 2: Schematic representation of self-assembly of C_{3h} and C_s rotational isomers of TSANs into a helical Col phase where the constituent discs are slightly tilted and rotate around the columnar axis.

Investigators: C.V.Yelamaggad, A.S.Achalkumar, D.S.Shankar Rao and S. Krishna Prasad

LIQUID CRYSTAL TRIMERS COMPOSED OF BANANA-SHAPED AND ROD-LIKE ANISOMETRIC SEGMENTS

In an exploratory attempt to realize molecules capable of stabilizing optically biaxial mesophases, liquid crystal trimers (Fig. 1), which are formed by covalently linking a banana-shaped and two rod-like mesogenic segments via two flexible spacers of varying length and parity, the first of their kind, have been prepared and their phase behavior investigated. Contrary to expectation, all the trimers, irrespective of the variations in the length and parity of the spacer they possess, exhibit an enantiotropic nematic phase possessing uniaxial symmetry. The novelty of these compounds originate from the fact that the central banana-shaped segment, which is made of two salicylaldimine [*N*-(2-hydroxy-4-alkoxybenzylidene)aniline] cores featuring intramolecular hydrogen bonding between the H-atom of the hydroxy group and the N-atom of the imine functionality, induces special features to the molecules. Indeed, the parity of the spacer determines the phase sequence, phase transition temperatures (Fig. 2a) and associated enthalpy values (Fig. 2b); a metastable smectic phase with a relatively lower transition temperature was observed for the trimer comprising odd-parity (heptamethylene) spacer. This initial study provides insight into what could be a vast family of materials that are interesting from both fundamental research and application view points.

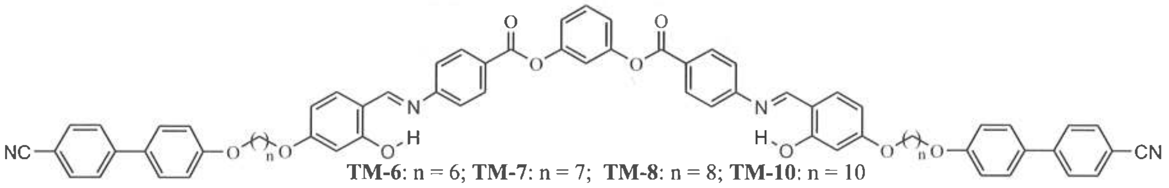


Figure 1. A general molecular structure of liquid crystal trimers

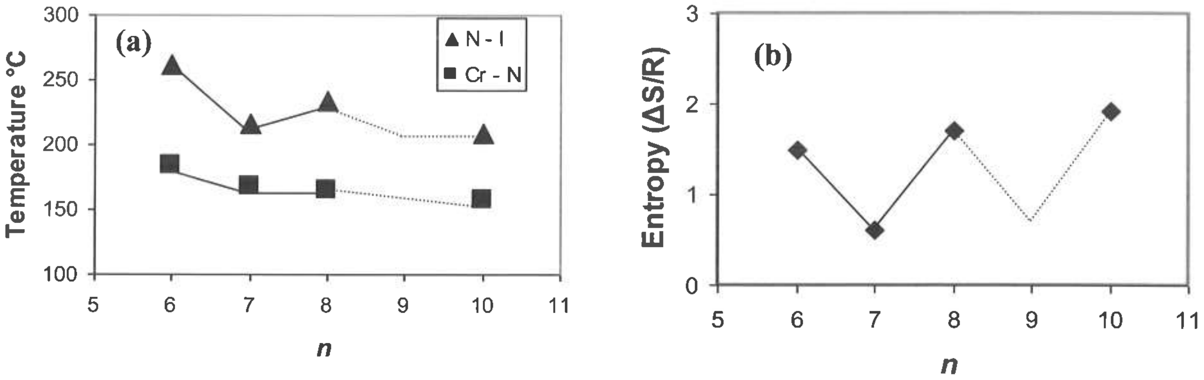


*Figure 2: The dependence of the transition temperatures (a) and the entropy changes associated with the N-I (b) phase transition on the number of methylene units (n) in the flexible alkyl spacers for **TM-n** series in heating cycle.*

Investigators: C. V. Yelamaggad and I. Shashikala
Collaborator : Quan Li, Liquid Crystal Institute, Kent State University, Kent, USA

INSTABILITIES ACROSS THE ISOTROPIC CONDUCTIVITY POINT IN A NEMATIC PHENYL BENZOATE UNDER AC DRIVING

This study relates to the sequence of bifurcations generated by ac fields in nematic 4-*n*-pentyloxyphenyl 4-*n*-decyloxybenzoate, held between unidirectionally rubbed ITO electrodes. The material, which possesses a negative dielectric anisotropy ε_a and an inversion temperature for electrical conductivity anisotropy σ_a, exhibits a monostable tilted alignment near T_{IN}, the isotropic-nematic point. On cooling, an anchoring transition to the homeotropic configuration occurs close to the underlying smectic phase.

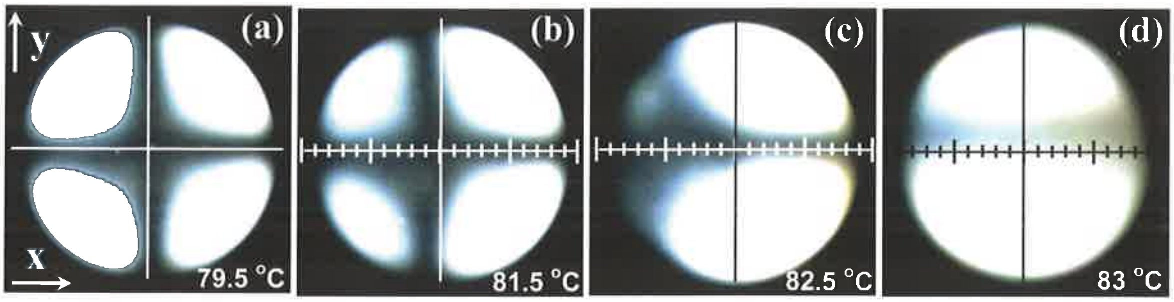


Figure: Interference figures under conoscopic examination between crossed polarizers corresponding to different temperature dependent orientations of the uniaxial structure. The figure is centred in (a); progressive leftward shift of the melatope in (b) to (d) shows the anchoring transition between homeotropic and monotilted states. The sequence is reversed on cooling. Each division on the horizontal scale is 10 μm.

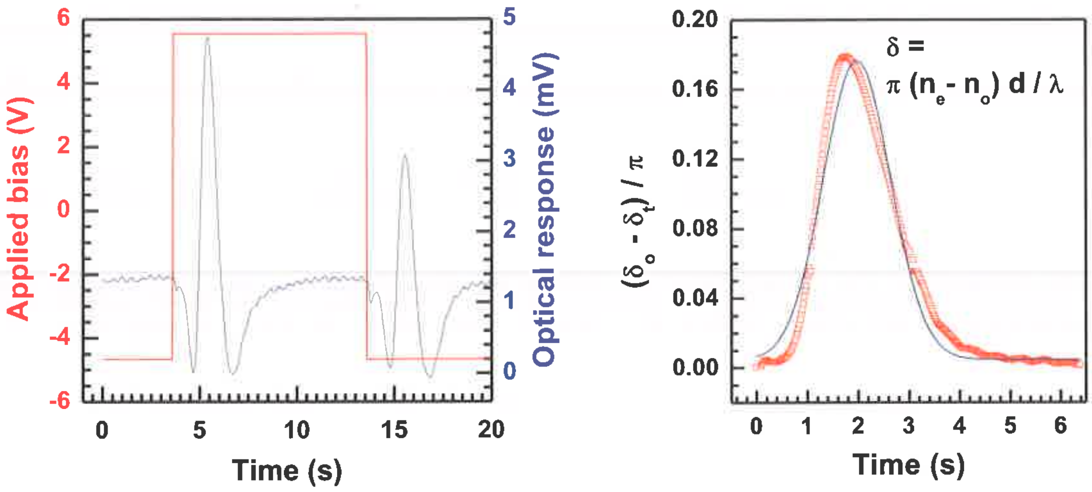
The field experiments are performed for (i) negative σ_a and homeotropic alignment, and (ii) weakly positive σ_a and nearly homeotropic alignment. Under ac driving, the Freedericksz transition is followed by bifurcation into various patterned states. Among them are the striped states that seem to belong to the dielectric regime, and localized hybrid instabilities. Very significantly, the patterned instabilities are not excited by dc fields, indicating their possible gradient flexoelectric origin. The Carr-Helfrich mechanism based theories that take account of flexoelectric terms can explain the observed electroconvective effects only in part.

Investigators: Pramoda Kumar, S. H. Uma and K.S.Krishnamurthy
Collaborator: S. N. Patil, Garden City College, Bangalore

EMERGENCE OF PERIODIC ORDER IN ELECTRIC FIELD DRIVEN PLANAR NEMATICS: AN EXCLUSIVE AC EFFECT ABSENT IN STATIC FIELDS

This work concerns a nematic with a low conductivity anisotropy (4-n-pentyloxyphenyl 4-n-decyloxybenzoate) that exhibits a new type of ac field generated transition from a uniformly planar to a periodically modulated director configuration with the wave vector parallel the initial director. Significantly, with unblocked electrodes, this instability is not excited by dc fields.

Additionally, in very low frequency square wave fields, it occurs transiently after each polarity reversal, vanishing completely during field-constancy, as indicated in the figure. The time of occurrence of maximum distortion after polarity reversal decreases exponentially with voltage. The time dependence of optical phase change during transient distortion is nearly Gaussian. The pattern threshold V_c is linear in $\sqrt{f}$, f denoting the frequency; the critical wavenumber q_c of the modulation scales nearly linearly as $\sqrt{f}$ to a peak at ~50 Hz before falling slightly thereafter. The observed V_c and q_c characteristics differ from the predictions of the standard model (SM). The instability may be interpreted as a special case of the Carr-Helfrich distortion suppressed in static fields due to weak charge focusing and strong charge injection. Its transient nature in the low frequency regime is suggestive of the possible role of gradient flexoelectric effect in its occurrence. The study includes measurement of certain elastic and viscosity parameters relevant to the application of the SM.



Left: *Electrooptic response in a planarly aligned sample at 82.6 °C, driven by a 50 mHz, 5 V square wave field; transient change in transmitted intensity follows each polarity reversal; diagonally crossed polarizers; mercury yellow light.*

Right: *Relative phase change in units of π as a function of time during the transient occurrence of periodic instability for 5 V. The continuous curve is the Gaussian fit*

Investigators: K.S.Krishnamurthy and Pramoda Kumar

National Science Day

The Centre celebrated the National Science Day on 28 February 2008. The Centre declared that day as Open Day for the public. The Centre invited about 40 children and a few teachers from BEL High School to the Centre and arranged for them a series of lectures by the Scientists of CLCR. The lectures were on :

(1) Science of water.
(2) Liquid crystals and modulation of light.
(3) States of matter and their unique properties.
(4) Flying trains and other phase transition phenomena in every day life.
(5) Surface forces.

There were also some slide shows and visit to the laboratories. The children showed great appreciation of the various programmes conducted at the Centre.

Prof. S.Chandrasekhar Memorial Lecture

The Centre is observing 6 August of every year as Founder's Day by arranging a Prof.S.Chandrasekhar Memorial Lecture. The fourth in the series was held on 6 August 2007 and the memorial lecture was delivered by Prof. T.V.Ramakrishnan FRS, Homi Bhabha Distinguished Professor, Banaras Hindu University, Varanasi on "Many Electrons Strongly Avoiding Each Other: Trying to Understand the Strange Goings On".

Students Programme

In order to expand the activities of the Centre, separate hostel facility to men and women students has been provided w.e.f. 1.7.2007 at Premier Residency, which is situated in Vidyaranyapura layout, about 2 kms away from CLCR. The research students are availing the hostel facility.

BEL School children and teachers at the CLCR campus on the Science Day.

School children curious about the research activities in the laboratory.

Visits abroad

Dr. Geetha G. Nair visited the Liquid Crystal Institute (LCI), Kent state University, Kent, USA during March 2007 - June 2007 to work with Prof. Antal Jakli of LCI on a Samsung Electronics sponsored project titled “Electro-optical switching based on field-induced biaxiality of bent-core liquid crystal mixtures”.

Talks given at the Conferences

- Dr. S.Krishna Prasad attended the 11th International Conference on Ferroelectric Liquid Crystals (FLC07) held at the Hokkoido University, Sapporo, JAPAN during 3-8 September 2007 as an invited speaker and made an oral presentation entitled “Photoinduced Effects in the Smectic C^*_A and Smectic C^*_{alpha} Phases. During his visit to Japan, he also visited National Institute of Advanced Industrial Science & Technology, Tsukuba from 9-11 September 2007.

- Under the auspices of Indian Liquid Crystal Society, the 14th National Conference on Liquid Crystals was conducted at the North Bengal University, Siliguri in collaboration with CLCR, during 17-19 December 2007. About 60 participants attended the conference; 30 papers and 28 posters were presented at the conference; out of these, 7 papers and 2 posters were by the Scientists and students of CLCR.

- Prof. K.A.Suresh attended “National Conference in Recent Trends in Optoelectronics and Laser Technology (NCOL 2007)” held at Thiruvananthapuram during 9-11 April 2007 and delivered a Plenary Talk entitled "Viscoelastic modes in thermotropic liquid crystals" at the Conference.

- Prof. K.A.Suresh attended the 14th National Conference on Liquid Crystals held at North Bengal University, Siliguri, during 17-19 December 2007 and gave an invited talk entitled “Films of novel discotic mesogenic molecules at interfaces”.

- Dr. S.Krishna Prasad attended the 14th National Conference on Liquid Crystals held at North Bengal University, Siliguri, during 17-19 December 2007 and gave an invited talk entitled “Evidence of wormlike micellar behaviour in chromonic liquid crystals”.

Miscellaneous

- **Vigilance Inspection Team**

  A Vigilance Inspection Team from the Department of Science and Technology, New Delhi, consisting of Shri. C.R.Gangadharan, Under Secretary (Vig.), Shri.Umesh Pande, Section Officer and Shri.A.K.Chattopadhyay, Assistant (Vig.) visited CLCR on 20 September 2007. They reviewed the action taken on vigilance related matters at CLCR. They also visited the Lab, Library and other facilities.

- **International Women’s Day**

  The Centre celebrated the International Women’s Day on 10 March 2008 at CLCR premises. A meeting was held at CLCR and the women of the Centre discussed various issues.

- **Elected as President of Indian Liquid Crystal Society**

  Prof. K.A.Suresh was elected as President of the Indian Liquid Crystal Society at the 14th National Conference on Liquid Crystals held at Siliguri, West Bengal, 17-19 December 2007.

- **Visit of Scientists from abroad and Talks / Colloquium / Seminar given at the Centre**

A colloquium was given by Dr.Sandeep Kumar, Scientist, Raman Research Institute on “Liquid Crystals: Current Status and Future Trends” on 25 October 2007 in connection with a Governing Council meeting held on that day.

Prof. Jung Ok Park, Georgia Institute of Technology, Atlanta, USA visited the Centre and gave a talk on “Forced coating of nematic fluids on cylindrical substrates: Non-classical scaling and instability development” on 5 December 2007.

Dr. Tamas Borzsonyi, Scientist, Research Institute of Solid State Physics & Optics of the Hungarian Academy of Sciences, Budapest, Hungary, visited CLCR for 2 weeks from 8 December 2007 to 21 December 2007 under INSA-HAS Joint Research Projects Programme. During this period he also gave a talk on “Interfacial instabilities during mesophase growth: Experimental studies and numerical simulations” on 11 December 2007.

Prof. Carsten Tschierske, University Halle, Halle/Saale, Germany visited CLCR and gave a talk on “Silicon containing bent-core molecules . from polyphilic molecules via dimers and oligomers to dendrimers and polymers” on 12 December 2007.

Prof. Mitsuyoshi Onoda, Graduate School of Engineering, University of Hyogo, Japan visited CLCR and gave a colloquium on “A proposal of molecularly doping methods for polymer devices: Maskless dye diffusion technique" on 26 December 2007.

- **National Conference of Women Scientists**

  Dr. Veena Prasad, Scientist, CLCR attended the National Conference of Women Scientists organised by the Department of Science & Technology, held at Vigyan Bhavan, New Delhi during March 8-10, 2008.

Names of Scientists and Researchers working in the Centre as on 31.03.2008 :

Name		Designation
1.	Prof. K.A.Suresh	Director
2.	Dr. S.Krishna Prasad	Scientist E
3.	Dr. Geetha G.Nair	Scientist C
4.	Dr. D.S.Shankar Rao	Scientist C
5.	Dr. Veena Prasad	Scientist C
6.	Dr. C.V.Yelamaggad	Scientist C
7.	Prof. K.S.Krishnamurthy	Emeritus Scientist
8.	Dr. Uma S.Hiremath	Research Associate
9.	Dr. V.Padmini	Research Associate
10.	Mr. G.Shanker	Senior Research Fellow
11.	Mr. Pramoda Kumar	Senior Research Fellow
12.	Ms. Jayalakshmi	Junior Research Fellow
13.	Ms. S.Sridevi	Junior Research Fellow
14.	Mr. Pramod Tadapatri	Junior Research Fellow
15.	Mr. Prasad N.Bapat	Junior Research Fellow
16.	Ms. Rashmi Prabhu	Project Assistant
17.	Ms. Sridevi A.N.	Project Assistant

Administrative Staff during the year 2007-2008 :

Name	Designation
1. Shri. N.R.Gopinath	Administrative Officer
2. Shri. K.P.N.Rao	Administrative Officer (w.e.f. 1.10.2008)
3. Shri. K.R.Shankar	Accounts Officer
4. Shri. P.K.Ramakrishnan	Engineer
5. Shri. Sanjay K.Varshney	Technical Assistant
6. Smt. Sandhya D.Hombal	Technical Assistant
7. Smt. P.Nethravathi	Selection Grade U.D.C
8. Smt. V.Anupama	U.D.C.
9. Shri. Govindappa	Consultant in Administration

PUBLICATIONS DURING 2007-2008

Papers published

In Journals

1) Discogen-DNA complex films at air-water and air-solid interfaces, Alpana Nayak and K.A.Suresh, *J. Phys. Chem. B*, **112**, 2930 (2008).

2) Conductivity of Langmuit-Blodgett films of a disk-shaped liquid crystalline molecular-DNA complex studied by current sensing atomic force microscopy, Alpana Nayak and K.A.Suresh, *Phys. Rev. E*, **78,** 021606 (2008).

3) Extraordinary properties of nematic phases of bent-core liquid crystals, A.Jákli, M. Chambers, J. Harden, M. Madhabi, R. Teeling, J. Kim, Q. Li, Geetha G. Nair, N. Éber, K. Fodor-Csorba, J.T. Gleeson, S. Sprunt, *SPIE*, **6911**, 691105 (2008).

4) Optically biaxial interdigitated smectic A phase : Liquid crystalline dimeric bidentate ligands and their metal complexes, C. V. Yelamaggad, I.Shashikala, V. Padmini, D. S. Shankar Rao, Geetha G. Nair, and S.Krishna Prasad; *J. Mater. Chem.*, **18**, 2096-2103 (2008).

5) Electric-field assisted acceleration of the photostimulated nematic-isotropic transition, S. Krishna Prasad, Geetha G. Nair and V. Jayalakshmi, *Adv. Mat.* **20**, 1363 (2008).

6) Effect of aerosil dispersions on the photoinduced nematic–isotropic transition, V Jayalakshmi, Geetha G Nair and S Krishna Prasad, *J. Phys.: Condens. Matter*, **19**, 226213 (2007)

7) Evidence of wormlike micellar behavior in chromonic liquid crystals: rheological, x-ray, and dielectric studies, S. Krishna Prasad, Geetha G. Nair, Gurumurthy Hegde and V. Jayalakshmi, *J. Phys. Chem. B,* **111**, 9741 (2007).

8) Dependence of the thermal back relaxation time kinetics on the order parameter excess between the equilibrium and photo-stimulated states, V.Jayalakshmi, Geetha G. Nair and S. Krishna Prasad, *Phys. Rev. E.*, **75**, 031710 (2007)

9) Monodispersive linear supermolecules stabilizing unusual fluid layered phases, C. V. Yelamaggad, A. S. Achalkumar, D. S. Shankar Rao and S.Krishna Prasad, *Organic Letters*, **9**, 2641 (2007).

10) A new class of discotic mesogens derived from Tris(N-salicylideneaniline)s existing in C3h and Cs Keto-Enamine forms, C. V. Yelamaggad, A.S.Achalkumar, D. S. Shankar Rao, and S. Krishna Prasad, *J. Org. Chem.*, **72**, 8308 (2007).

11) The first examples of optically active tris(N-salicylideneaniline)s: manifestation of chirality from molecules to fluid columnar phases, C.V.Yelamaggad, A. S. Achalkumar, D. S. Shankar Rao and S. Krishna Prasad, *J. Mater. Chem.*, **17**, 4521 (2007).

12) Studies of the mesomorphic behavior of bivalent carbohydrate amphiphiles, N. Jayaraman, M. K. Singh, D. S. Shankar Rao and S. Krishna Prasad, *J. Mater. Chem.,* **17**, 2228 (2007).

13) Frustrated liquid crystals: Synthesis and mesomorphic behavior of unsymmetrical dimers possessing chiral and fluorescent entities, C.V.Yelamaggad, N. L. Bonde, A.S. Achalkumar, D. S. Shankar Rao, S. Krishna Prasad, and A. K. Prajapati, *Chem. Mater.*, **19**, 2463 (2007).

14) Dependence of the thermal back relaxation time kinetics on the order parameter excess between the equilibrium and photo-stimulated states, V.Jayalakshmi, Geetha G. Nair and S. Krishna Prasad, Phys. Rev. E., **75**, 031710 (2007)

15) High nematic ordering in a bent-core smectogen showing a baxial nematic phase: a ^{13}C NMR study, R.Y. Dong, S. Kumar, Veena Prasad and J.Zhang, *Journal of Chemical Physics Letters,* **54**, 448 (2007).

16) Instabilities across the isotropic conductivity point in a nematic phenyl benzoate under AC driving, Pramoda Kumar, Shivaram N. Patil, Uma S.Hiremath and K. S. Krishnamurthy, *J. Phys. Chem. B*, **111**, 8792 (2007).

17) Emergence of periodic order in electric field driven planar nematics: an exclusive ac effect absent in static fields, K. S. Krishnamurthy and Pramoda Kumar, *Phys. Rev. E,* **76**, 051705 (2007).

18) Mesomorphic chiral nonsymmetrical dimers : synthesis and characterization, C. V. Yelamaggad and G. Shanker, *Liq. Cryst.*, **34**, 799 (2007).

19) Synthesis and characterization of nonsymmetric chiral dimers, C.V.Yelamaggad and G. Shanker; *Liq. Cryst.*, **34**, 1045 (2007).

20) Characteristic dielectric behaviour of the wide temperature range twist grain boundary phases of unsymmetrical liquid crystal dimers, M. B. Pandey, R.Dhar, A. S. Achalkumar and C. V. Yelamaggad, *J. Phys.: Condens. Matter*, **19**, 43621 (2007)

21) Liquid crystal trimers composed of banana-shaped and rod-like anisometric segments: Synthesis and characterization, C. V. Yelamaggad, I. Shashikala and Q. Li; *Chem. Mater.,***19**, 6561 (2007).

IN PRESS

In Journals

22) Synthesis and mesogenic properties of β-tetrabrominated tetraalkyloxyporphyrins, P. Bhyrappa, C. Arunkumar, B. Varghese, D. S. Shankar Rao and S. Krishna Prasad, *Journal of Porphyrins and Phthalocyanines*, (in press).

23) *Electrically tunable color using mixtures of bent-core and rod-shape molecules,* Geetha.G. Nair, C. A. Bailey, S.Taushanoff, K. Fodor-Csorba, A. Vajda, Z. Varga, A. Bóta, A. Jákli, *Adv. Mat.* (In press)

24) *Electric-field assisted acceleration of the photostimulated nematic-isotropic transition*, S. Krishna Prasad, Geetha G. Nair and V. Jayalakshmi, *Adv. Mat.* (In press)

PAPERS & POSTERS PRESENTED AT THE CONFERENCES :

1) *Effect of confinement on phase transition in liquid crystals*, D.S.Shankar Rao, paper presented (oral) at the 14th National Conference on Liquid Crystals, December 17-19, 2007 organized by Department of Physics, University of North Bengal, Siliguri, West Bengal.

2) *Molecules to mesogenic phasmidic type materials through inter-molecular hydrogen bonding*, Veena Prasad and Sanjay K. Varshney, Poster presented at the 14th National Conference on Liquid Crystals, December 17-19, 2007 organized by Department of Physics, University of North Bengal, Siliguri, West Bengal.

3) *Electrically driven instabilities in the smectic C and nematic phases of a phenyl benzoate*, Pramoda Kumar and K. S. Krishnamurthy, Paper presented at the 14th National Conference on Liquid Crystals, December 17-19, 2007 organized by Department of Physics, University of North Bengal, Siliguri, West Bengal.

4) *Optically active nonsymmetric liquid crystal dimers: Synthesis and characterization*, G. Shanker and C. V. Yelamaggad, Paper presented at the 14th National Conference on Liquid Crystals, December 17-19, 2007 organized by Department of Physics, University of North Bengal, Siliguri, West Bengal.

5) *Optically biaxial interdigitated smectic A phase: Mesomorphic dimeric bidentate ligands and their metal complexes*, V. Padmini Tamilenthi, I.S.Shashikala and C. V. Yelamaggad, Paper presented at the 14th National Conference on Liquid Crystals, December 17-19, 2007 organized by Department of Physics, University of North Bengal, Siliguri, West Bengal.

6) *Electric-field assisted acceleration of the photostimulated nematic-isotropic transition*, S. Krishna Prasad, Geetha G. Nair and V. Jayalakshmi, Paper presented at the 14th National Conference on Liquid Crystals, December 17-19, 2007 organized by Department of Physics, University of North Bengal, Siliguri, West Bengal.

7) *Synthesis of non-symmetric discotic oligomers using triphenylene and anthraquinone monomers,* Sanjay K. Varshney and Veena Prasad, Poster presented at the 14th National Conference on Liquid Crystals, December 17-19, 2007 organized by Department of Physics, University of North Bengal, Siliguri, West Bengal.

CENTRE FOR LIQUID CRYSTAL RESEARCH
BANGALORE

STATEMENT OF ACCOUNTS
FOR THE YEAR 2007 – 2008
AND
THE BALANCE SHEET AS ON 31.03.2008

SANTHAPPA & CO.,
CHARTERED ACCOUNTANTS

Unit No. 201, II Floor, House of Lords, 15 & 16, St. Mark's Road, Bangalore - 560 001. Phone : 22210717 / 22210032. Telefax : 22270335

AUDITORS REPORT

We have audited the attached Balance Sheet of the **Centre For Liquid Crystal Research, Jalahalli, Bangalore,** as at 31st March 2008, the Income and Expenditure Account and Receipts and Payments Account for the year ended on the date. These financial Statements drawn up by the Institute are the responsibility of the Institute's management. Our responsibility is to express an opinion on these financial statements based on our audit.

We Conducted our audit in accordance with auditing standard generally accepted in India. Those standard require what we plan and perform the audit to obtain reasonable assurance about whether the financial statements are free of material misstatement . An audit includes examining on test basis, evidence supporting the amounts and disclosure in the financial statements . An audit also includes assessing the accounting principles used and significant estimates made by the management as well as evaluating the overall financial statement presentation . We believe that our audit provides a reasonable basis for our opinion.

We have obtained all the information and explanations, which to best of our Knowledge and belief, were necessary for the purposes of our audit . The Balance Sheet and the Income and Expenditure Account dealt with by the report are in agreement with books of account maintained by the Institute.

It is the Policy of the Institute to prepare its financial statements on the cash receipts and disbursements basis. On this basis, revenue and related assets are recognized when received rather than earned. The expenses are recognized when paid rather than when the obligation is incurred.

In our opinion , and to the best of our information and according to the explanations given to us, the financial statements read with significant accounting policies and notes on accounts thereon give a true and fair view in conformity with the accounting principles generally accepted in India:

i. Of the assets and liabilities arising from cash transanctions of the Centre for Liquid Crystal Research as at 31.03.2008.

ii. Of the revenue collected and expenses paid during the year ended on the cash receipt and disbursement basis.

For Santhappa & Co,
Chartered Accountants,

(A.C.Raju)
Partner.
M.No.18134

Place: Bangalore
Date: 05.08.2008

CENTRE FOR LIQUID CRYSTAL RESEARCH, JALAHALLI, BANGALORE - 560 013.
BALANCE SHEET AS AT 31ST MARCH, 2008

(Amount in Rupees)

I. CORPUS / CAPITAL FUND AND LIABILITIES	SCHEDULE	CURRENT YEAR	PREVIOUS YEAR
CORPUS / CAPITAL FUND	1	46434537	23826422
RESERVES AND SURPLUS	2	N I L	N I L
EARMARKED / ENDOWMENT FUNDS PROJECTS	3	7778785	6222335
SECURED LOANS AND BORROWINGS	4	N I L	N I L
UNSECURED LOANS AND BORROWINGS	5	N I L	N I L
DEFERRED CREDIT LIABILITIES	6	N I L	N I L
CURRENT LIABILITIES AND PROVISIONS	7	49682	35106
DEFERRED GOVT. GRANTS	8	46543632	43706955
TOTAL		100806637	73790818
II ASSETS			
FIXED ASSETS	9	38674745	37486092
INVESTMENTS - FROM EARMARKED/ENDOWMENT FUNDS	10	N I L	N I L
INVESTMENTS - OTHERS	11	N I L	N I L
CURRENT ASSETS, LOANS, ADVANCES ETC.,	12	62131891	36304726
MISCELLANEOUS EXPENDITURE (to the extent not written off or adjusted)		N I L	N I L
TOTAL		100806637	73790818
NOTES ON ACCOUNTS	25		

As per our report of even date annexed,
for SANTHAPPA & CO.,
Chartered Accountants,

(A.C.RAJU)
Partner

K.R. Shankar
(K.R.SHANKAR)
ACCOUNTS OFFICER

(K.A.SURESH)
DIRECTOR

PLACE: BANGALORE
DATE : 05.08.2008

CENTRE FOR LIQUID CRYSTAL RESEARCH, JALAHALLI, BANGALORE - 560 013.
INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31ST MARCH, 2008

(Amount in Rupees)

A - INCOME	SCHEDULE	CURRENT YEAR	PREVIOUS YEAR
Income from Sales / Services	13	N I L	N I L
Grants / Subsidies:	14	31728861	N I L
Fees / Subscriptions	15	N I L	N I L
Income from Investments(income on investments from		N I L	N I L
earmarked / endownment Funds)	16	N I L	N I L
Income from Royalty, Publications etc.,	17	N I L	N I L
Interest earned	18	2552504	2133997
Other Income	19	5489084	5585555
Increase / (decrease) in stock of finished goods and work-in-progress	20	N I L	N I L
TOTAL (A)		39770448	7719552
B - EXPENDITURE			
Establishment Expenses	21	3316415	2781924
Other Administrative Expenses etc.,	22	8411457	6799954
Expenditures on Grants, Subsidies etc.,	23	N I L	N I L
Interest	24	N I L	N I L
Depreciation (Net Total at the year end corresponding to schedule 9 (A)		5434462	5499877
TOTAL (B)		17162334	15081755
BALANCE BEING SURPLUS / (DEFICIT) CARRIED TO CORPUS / CAPITAL FUND (A-B)		22608115	-7362203
NOTES ON ACCOUNTS	25		

As per our report of even date annexed,
for SANTHAPPA & CO.,
Chartered Accountants,

(A.C.RAJU)
Partner

(K.A.SURESH)
DIRECTOR

K.R. Shankar
(K.R.SHANKAR)
ACCOUNTS OFFICER

PLACE: BANGALORE
DATE : 05.08.2008

CENTRE FOR LIQUID CRYSTAL RESEARCH, JALAHALLI, BANGALORE - 560 013.

RECEIPTS AND PAYMENTS FOR THE PERIOD / YEAR ENDED 31ST MARCH, 2008

(Amount in Rupees)

	RECEIPTS	Current Year	Previous Year		PAYMENTS	Current Year	Previous Year
I	**Opening Balances**			I	**Expenses**		
	a) Cash in Hand	7727	9718		a) Establishment Expenses	3316415	2781924
	b) Bank Balances	549876	484245		b) Administrative Expenses	8342130	6800674
II	**Grants Received**			II	**Payments made against Funds**		
	a) From Govt.of India	40000000	NIL		**for various Projects**	634168	647891
	b) From Other Sources						
	i) CSIR (1931_CVY) Project	288731	217940	III	**Investments and Deposits**		
	ii) SERC (2004-05) Project	600000	NIL		**Made out of own Funds**	128674106	40408637
	iii) SERC (CVY1) Project	2000000	NIL				
III	**Income on Investments from**			IV	**Expenditure on**		
	a) Earn/Endowment Funds	NIL	NIL		a) Fixed assets	7390555	867384
	b) Own Funds	NIL	NIL		b) Capital Work in Progress	NIL	NIL
IV	**Interest Received**			V	**Refund of Surplus money/Loans**	NIL	NIL
	a) On Bank Deposits (S.B)	18054	17626		**EMD / Security Deposit**	NIL	NIL
	b) Loans, Advances, Deposits etc.,	2534450	2116372				
				VI	**Finance Charges (Interest)**	NIL	NIL
	Other Income (Specify)						
V	Miscellaneous Receipts, CHSS	12350	35678				
	INSA-HAS Workshop	NIL	50000	VII	**Other Payments (Specify)**	NIL	NIL
	Reimbursement of Fellowship	NIL	NIL		Income Tax	252409	NIL
	Miscellaneous Income	35987	NIL		Contributions recovered & remitted to RR	12450	NIL
	Licence Fee	6285	NIL		CPF	201389	NIL
VI	**Amount Borrowed**	NIL	NIL	VIII	**Closing Balances**		
					a) Cash in Hand	7660	7727
VII	**Any Other Receipts**				b) Bank Balances	2714318	549876
	EMD	14576	7655				
	Advances	41720	NIL				
	Income Tax	252409	56043				
	Contributions recovered & remitted to RF	12450	NIL				
	CPF	201389	NIL				
	NSC	1000	NIL				
	IT refund received	281018	NIL				
VIII	**Investments & Deposits Matured**	104687578	49068836				
	TOTAL	151545600	52064113		TOTAL	151545600	52064113

As per our report of even date annexed,
for SANTHAPPA & CO.,
Chartered Accountants,

K.R.Shankar

(K.A.SURESH)
DIRECTOR

(K.R.SHANKAR)
ACCOUNTS OFFICER

(A.C.RAJU)
Partner

PLACE: BANGALORE
DATE : 05.08.2008

CENTRE FOR LIQUID CRYSTAL RESEARCH, JALAHALLI, BANGALORE - 560 013.
SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31ST MARCH, 2008

(Amount in Rupees)

		CURRENT YEAR	PREVIOUS YEAR
SCHEDULE 1 - CORPUS / CAPITAL FUND			
Balance as at the beginning of the year		23826422	31188625
LESS: Amount transferred to deferred grant A/c		0	0
		23826422	31188625
ADD: Excess of Expenditure over Income		22608115	-7362203
	TOTAL	46434537	23826422
SCHEDULE 2 - RESERVES AND SURPLUS		NIL	NIL
SCHEDULE 3 - EARMARKED / PROJECT FUNDS	**TOTAL**	7778785	6222335
(See Annexure A for details)			
SCHEDULE 4 - SECURED LOANS AND BORROWINGS		NIL	NIL
SCHEDULE 5-UNSECURED LOANS AND BORROWINGS		NIL	NIL
SCHEDULE 6-DEFERRED CREDIT LIABILITIES		NIL	NIL
SCHEDULE 7-CURRENT LIABILITIES & PROVISIONS			
A) CURRENT LIABILITES:			
1) Statutory Liabilites - Professional Tax		0	0
2) Other Liabilities - Security Deposit		49682	35106
	TOTAL (A)	49682	35106
B) PROVISIONS:		NIL	NIL
	TOTAL (B)	NIL	NIL
	TOTAL (A+B)	49682	35106
SCHEDULE 8 - DEFERRED GRANT			
Balance as at the beginning of the year		43706955	49206832
ADD: Grants received during the year		8271139	0
		51978094	49206832
LESS: Transferred to Deferred Grant Income		5434462	5499877
	TOTAL	46543632	43706955

CENTRE FOR LIQUID CRYSTAL RESEARCH, ALAHALLI, BANGALORE - 560 013.
SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31ST MARCH, 2008

Annexure A to Schedule 3

(Amount In Rupees)

SCHEDULE 3 - EARMARKED / PROJECTS FUNDS	SERC	SERC (2004-05	SERC (CVY1)	PROJECT / WISE BREAKUP INDO-US	INDO-US (SKP)	INDO - JAPAN	CSIR (NMITLI)	CSIR (SK)	CSIR (CVY)	CSIR 931_CV	CSIR 2162_CVY3	INDO-ITALIAN	TOTAL CURRENT YEAR	PREVIOUS YEAR
a) Opening Balance of the Funds	2947700	233928	0	477745	285105	175319	1727850	169580	29378	62730	0	113000	6222335	7393928
b) Additions to the Funds:														
i) Grants	0	600000	2000000	0	0	0	0	0	0	288731	0	0	2888731	217940
ii) Incomefrom Investments made on Account of India														
iii) Other Additions (Specify nature)														
TOTAL (a+b)	2947700	833928	2000000	477745	285105	175319	1727850	169580	29378	351461	0	113000	9111066	7611868
c) Utilisation/Expenditure towards objective of Funds:														
i) Capital Expenditure														
Fixed Assets														
Others														
ii) Revenue Expenditure														
Salaries, Wages and Allowances etc.,	0	204145	20830	—	0	—	0	0	0	351461	8665	0	585101	375443
Consumables	0	33332	0	—	—	—	0	0	0	0	0	0	33332	0
Depreciation	343817	32069	1180	23388	42773	—	259369	6801	4450	0	0	0	713848	838768
Overheads	0	0	0	—	0	—	0	0	0	0	0	0	0	175322
TOTAL (c)	343817	269546	22010	23388	42773	—	259369	6801	4450	351461	8665	0	1332281	1389533
NET BALANCE AT THE YEAR END (a+b-c)	2603883	564382	1977989	454357	242332	175319	1727851	162779	24928	0	-8665	113000	7778785	6222335

CENTRE FOR LIQUID CRYSTAL RESEARCH, JALAHALLI, BANGALORE - 560 013.
SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31ST MARCH, 2008

SCHEDULE - 9 : FIXED ASSETS

(Amount in Rupees)

		GROSS BLOCK						DEPRECIATION BLOCK				NET BLOCK	
DESCRIPTION	Rate	Cost as on 01.04.2007	Additions/deletions during the year				Total	Depreciation as on 1.4.2007	Deletions	Depreciation for the year 2007-08	Total Depreciation as on 31.3.2008	W.D.V. as on 31.03.2008	W.D.V. as on 31.03.2007
			Before Sept.	After Sept.	Total additions	Total Deletions							
A. C L C R :													
Equipment	15	3782707	554101	490796	1044897	230139	4597465	2367055	147612	285482	2504925	2092540	1415652
Furniture & Fixtures	10	1193104	159274	45569	204843	0	1397947	571866	0	80330	652196	745750	621238
Scientific Equipment	15	68532031	0	5322574	5322574	0	73854605	43084219	0	4216365	47300584	26554021	25447812
Workshop Equipment	15	957807	0	0	0	0	957807	665346	0	43869	709215	248592	292461
Generator Set	15	947666	0	0	0	0	947666	554397	0	58990	613387	334278	393269
Air Conditioner	15	801337	24000		24000	0	825337	557086	0	40238	597324	228013	244251
Annexe Building	10	1703931	0	0	0	0	1703931	520596	0	118334	638930	1065002	1183335
Carpentary Works	10	826007	17996	33123	51119	0	877126	362676	0	49789	412465	464661	463331
Vinyl Flooring	10	252452	18938	0	18938	0	271390	114569	0	15682	130251	141139	137883
Fume Cupboard	10	206227	0	0	0	0	206227	103641	0	10259	113900	92327	102586
Aluminium Partitions	10	872090	60106	0	60106	0	932196	574080	0	35812	609892	322304	298010
Brick Base(Partitions)	10	54903	0	0	0	0	54903	22483	0	3242	25725	29178	32420
Other Miscellaneous Works	10	3352496	87654	125988	213642	0	3566138	1360096	0	214305	1574401	1991737	1992400
Construction of Shed	10	75662	0	0	0	0	75662	3783	0	7188	10971	64691	71879
Construction of Cycle Stand	10	0		86259	86259	0	86259	0	0	4313	4313	81946	0
Computers	60	1346646	377377	0	377377	0	1724023	1306913	0	250266	1557179	166844	39733
Total (A) Rs.		84905066	1299446	6104309	7403755	230139	92078682	52168806	147612	5434462	57455656	34623026	32736260
B. SERC PROJECT:													
Electrical Installation	15	683890	0	0	0	0	683890	475437	0	31268	506705	177185	208453
Equipment	15	6833738	0	0	0	0	6833738	4750782	0	312443	5063225	1770513	2082956
Cycle	15	1895	0	0	0	0	1895	1194	0	105	1299	596	701
Total (B) Rs.		7519523	0	0	0	0	7519523	5227413	0	343817	5571230	1948294	2292110

Contd ....

(Amount in Rupees)

DESCRIPTION	Rate	GROSS BLOCK						DEPRECIATION BLOCK				NET BLOCK	
		Cost as on 01.04.2007	Additions/deletions during the year Before Sept.	After Sept.	Total additions	Total Deletions	Total	Depreciation as on 1.4.2007	Deletions	Depreciation for the year 2007-08	Total Depreciation as on 31.3.2008	W.D.V. as on 31.03.2008	W.D.V. as on 31.03.2007
SCHEDULE 9 - Contd...													
C. INDO US PROJECT:													
Equipment	15	372254	0	0	0	0	372254	240912	0	19701	260613	111641	131342
Temperature Controller	15	32900	0	0	0	0	32900	22872	0	1504	24376	8524	10028
Cell Fabrication	15	47736	0	0	0	0	47736	33186	0	2183	35369	12368	14550
Total (C) Rs.		452890	0	0	0	0	452890	296970	0	23388	320358	132532	155921
D. INDO US (SKP) PROJECT:													
Equipment	15	761793		0	0	0	761793	476643	0	42773	519416	242378	285150
Total (D) Rs.		761793	0	0	0	0	761793	476643		42773	519416	242378	285150
E. CSIR (NMITLI) PROJECT:													
Equipment	15	5667314	0	0	0	0	5667314	3939890	0	259114	4199004	1468310	1727424
Computers	60	41400	0	0	0	0	41400	40975	0	255	41230	170	425
Total (E) Rs.		5708714	0	0	0	0	5708714	3980865		259369	4240234	1468479	1727848
F. CSIR (SK) PROJECT:													
Equipment	15	148760	0	0	0	0	148760	103418	0	6801	110219	38541	45342
Total (F) Rs.		148760	0	0	0	0	148760	103418		6801	110219	38541	45342
G. CSIR (CVY) PROJECT:													
Equipment	15	97326	0	0	0	0	97326	67660	0	4450	72110	25216	29666
Total (G) Rs.		97326	0	0	0	0	97326	67660		4450	72110	25216	29666
H. SERC (2004-05) PROJECT:													
Equipment	15	295908	0	0	0	0	295908	82114	0	32069	114183	181725	213794
Total (H) Rs.		295908	0	0	0	0	295908	82114	0	32069	114183	181725	213794
I. SERC (CVY1) PROJECT:													
Equipment	15	0	0	15735	15735	0	15735	0	0	1180	1180	14555	0
Total (H) Rs.		0	0	15735	15735	0	15735	0	0	1180	1180	14555	0
Grand Total(A+B+C+D+E+F+G+H)		**99889980**	**1299446**	**6120044**	**7419490**	**230139**	**107079331**	**62403889**	**147612**	**6148308**	**68404585**	**38674745**	**37486092**

CENTRE FOR LIQUID CRYSTAL RESEARCH, JALAHALLI, BANGALORE - 560 013.
SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31ST MARCH, 2008

(Amount in Rupees)

	CURRENT YEAR	PREVIOUS YEAR
SCHEDULE 10 - INVESTMENTS FROM EARMARKED / ENDOWMENT FUNDS	NIL	NIL
SCHEDULE 11 - INVESTMENTS - OTHERS	NIL	NIL
SCHEDULE 12-CURRENT ASSETS,LOANS, ADVANCES		
A) CURRENT ASSETS:		
1) Inventories	NIL	NIL
2) Sundry Debtors:	NIL	NIL
3) Cash Balances in Hand(including Cheques/Drafts and Imprest)	7660	7727
4) Bank Balances:- Scheduled Banks		
Current Account	NIL	NIL
Deposits Account (includes margin money)	58926829	34940301
Savings Accounts	2714318	549876
5) Post Office Savings Account - NSC	0	1000
TOTAL (A)	61648807	35498904
B) LOANS,ADVANCES AND OTHER ASSETS:		
1) Loans	NIL	NIL
2) Advances and Other amounts recoverable in Cash or in kind or for value to be received:	44230	85950
a) K P T C L Deposit (SERC/CLCR)	347740	347740
b) Telephone	76000	76000
c) Income Tax	0	0
3) Claims Receivable:		
Tax Deducted at Sources	15114	296132
TOTAL (B)	483084	805822
TOTAL (A+B)	62131891	36304726

SANTHAPPA & CO. ★ CHARTERED ACCOUNTANTS BANGALORE

CENTRE FOR LIQUID CRYSTAL RESEARCH, JALAHALLI, BANGALORE - 560 013.

SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31ST MARCH, 2008

		(Amount in Rupees)	
		CURRENT YEAR	PREVIOUS YEAR
SCHEDULE 13-INCOME FROM SALES / SERVICES		N I L	N I L
SCHEDULE 14 - GRANTS / SUBSIDIES			
(Irrevocable Grants & Sbusidies Received)			
Central Government Plan DIT		31728861	0
SCHEDULE 15 - FEES / SUBSCRIPTIONS		N I L	N I L
SCHEDULE 16 - INCOME FROM INVESTMENTS		N I L	N I L
SCHEDULE 17 - INCOME FROM ROYALTY, PUBLICATIONS ETC.,		N I L	N I L
SCHEDULE 18 - INTEREST EARNED			
1) On Term Deposits - Scheduled Bank		2534450	2116372
2) On Savings Accounts - Scheduled Bank		18054	17625
	TOTAL	2552504	2133997
SCHEDULE 19 - OTHER INCOME			
Miscellaneous Income		54622	35678
Deferred Grant Income		5434462	5499877
INSA-HAS Workshop Grant		0	50000
		5489084	5585555
SCHEDULE 20 - INCREASE (DECREASE) IN STOCK OF FINISHED GOODS & WORK IN PROGRESS		N I L	N I L
SCHEDULE 21 - ESTABLISHMENT EXPENSES			
1) Salaries and Wages		3304683	2755146
2) Others - Medical Expenses		11732	26778
	TOTAL	3316415	2781924

SANTHAPPA & CO.

CENTRE FOR LIQUID CRYSTAL RESEARCH, JALAHALLI, BANGALORE - 560 013.
SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31ST MARCH, 2008

(Amount in Rupees)

SCHEDULE 22-OTHER ADMINISTRATIVE EXPENSES,ETC

		CURRENT YEAR	PREVIOUS YEAR
1)	PLAN:		
a)	Printing of Journals / Books	741897	1006904
b)	Seminar and Conferences	83063	182931
c)	Fellowship	1120696	998327
d)	Repairs & Maintenance of Building	403900	560806
e)	Repairs & Maintenance of Equipment	952021	706590
f)	Postage	33255	19234
g)	Telephones	111458	129392
h)	Printing & Stationery	215139	99434
I)	Electricity & Water	1013796	890872
j)	Travelling and Conveyance	696913	161795
k)	Audit fee	0	16836
l)	Advertisement charges	83449	0
m)	Packing and forwarding	54460	23377
n)	Miscellaneous Expenses	112688	113680
o)	Consumables	1430179	935658
p)	Bank Charges	22669	14886
q)	Hospitality	32001	10008
r)	Customs Duty (statutory minimum)	63205	101703
s)	N.M.R. Recording Charges	150518	111201
t)	Professional Charges	271104	228411
u)	Annual Fee/Internet Charges	12000	920
v)	Security / sweeping charges / Wages	411606	256778
w)	Insurance	107132	122166
x)	Other charges - Parliamentary Standing Commt. Visit	NIL	NIL
y)	Rent, Rates & Taxes	18,500	1000
z)	Rent	200,000	0
aa)	Expenditure on INSA-HAS workshop	0	51002
ab)	Income Tax related to previous year	0	56043
ac)	Loss on Sale of Asset	69,327	0
ad)	Miscellaneous expenditure	481	0
	TOTAL	8411457	6799954

SCHEDULE 23-EXPENDITURE ON GRANTS, SUBSIDIES ETC.,	NIL	NIL
SCHEDULE 24- INTEREST	NIL	NIL

CENTRE FOR LIQUID CRYSTAL RESEARCH,
JALAHALLI, BANGALORE

SCHEDULE 25

NOTES ON ACCOUNTS FOR THE YEAR ENDED 31ST MARCH, 2008

I. Significant Accounting Policies :

A. Accounting Convention :

The Financial Statements have been prepared under Cash System of Accounting.

B. Fixed Assets:

- i. Fixed Assets are shown at the cost of acquisition.
- ii. Expenditure and outlays of moneys on incomplete projects of a capital nature are shown as capital work in progress until such time these projects are completed and commissioned.
- iii. Depreciation on all assets is provided on WDV basis at rates as per Income Tax Rules.

C. Retirement Benefits:

Employer's contribution to provident fund is made annually at applicable rates to the Contributory Provident Fund.

D. Government Grants:

- i. Government grants are reckoned in the accounts as and when received. Such grants received against specific depreciable asset/project are treated as deferred income in the same proportion in which depreciation on related assets is charges.
- ii. Grants in the form of assets received free of cost are taken to books of account at nominal value of 5% without charging depreciation.

E. Project / Earmarked Funds:

Income relating to the projects have been credited to the respective projects' fund accounts. Likewise, all the revenue expenditure and depreciation on assets pertaining to the projects have been debited to the projects fund account.

F. Revenue Recognition:

Interest income is recognized as receipt basis.

SANTHAPPA & CO. CHARTERED ACCOUNTANTS BANGALORE

II. Other Notes :

A. Foreign Currency Transactions:

i) Value of Imports calculated on C I F Basis :

Capital goods	Rs.5338309
Stores, Spares and Consumables	Rs.621133

ii) Expenditure in foreign currency:

Travel	Rs.41063
Remittances and Interest payment to Financial Institutions / Banks in Foreign Currency	Nil

B. The grants received during the year has been bifurcated as revenue grant and deferred grant. The deferred grant has been credited to the extent of fixed assets purchased during this year Rs.74,03,755 and Rs.8,67,384 purchased during 2006-07. The balance of grants Rs.3,17,28,861 is treated as revenue grants for this year in the absence of bifurcation in the sanction order.

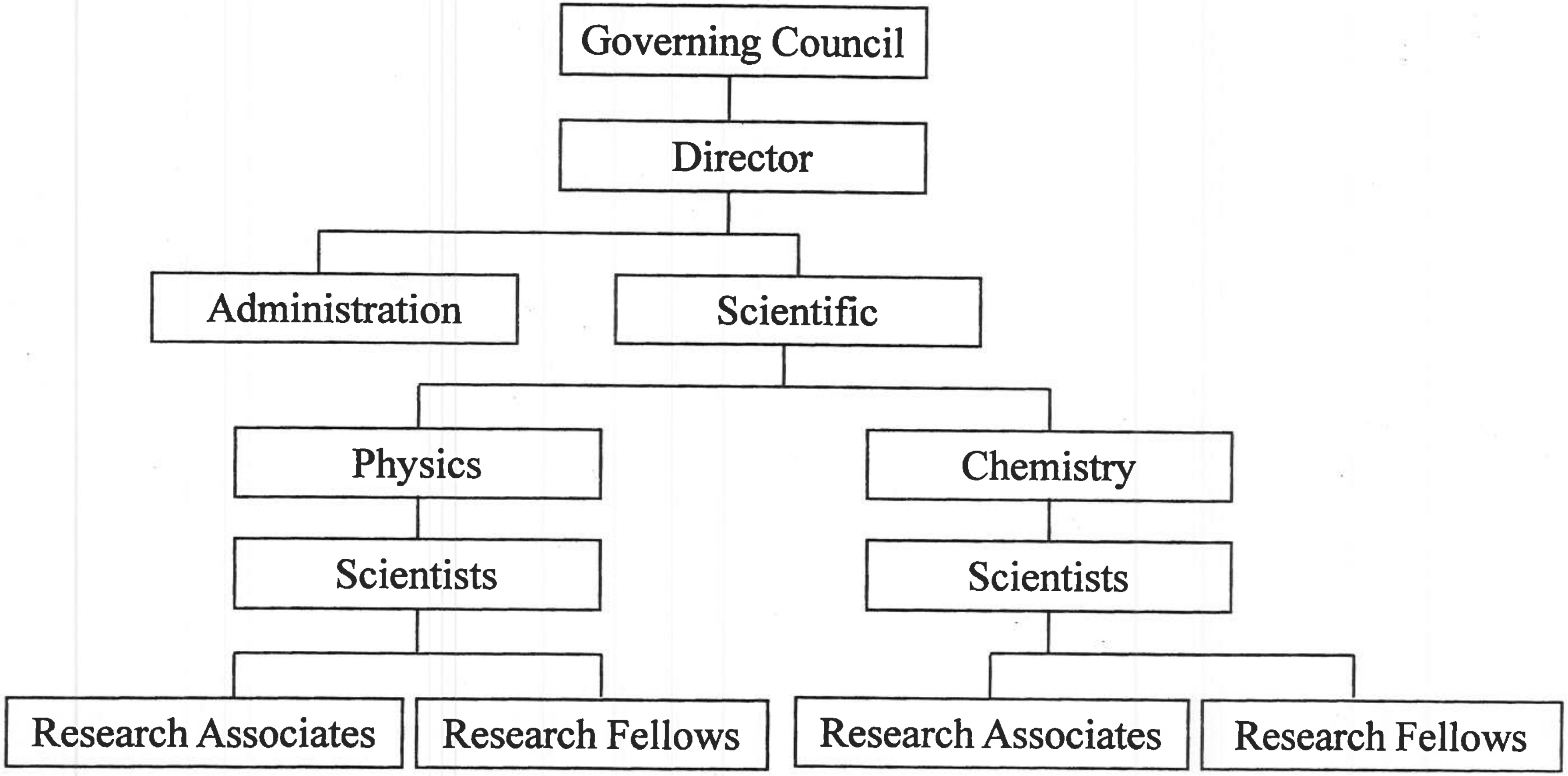
C. Previous year's figures have been regrouped wherever necessary to suit current year's presentation.

As per our report of even date.
for Santhappa & Co.
Chartered Accountants

(A.C.RAJU)
Partner
Membership No.18134

Place : BANGALORE
Date : 05.08.2008

Centre for Liquid Crystal Research (CLCR)
Organisation Chart



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