Centre for Soft Matter Research
Bengaluru

मृदु पदार्थ अनुसंधान केन्द्र
बेंगलूरु

ANNUAL REPORT
2012 – 2013

वार्षिक रिपोर्ट
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P.B. No.1329, Jalahalli
BENGALURU – 560 013

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FOREWORD

The Centre for Soft Matter Research (CSMR) is an autonomous institute under the Department of Science and Technology (DST), Ministry of Science and Technology, Government of India. The Centre is registered as a Scientific Society under the Karnataka Societies Act.

The Annual Report for the year 2012-2013 highlights the research and development activities, scientific programmes of the Centre, and lists the output of the Centre such as the academic activities and research publications for the period 1 April 2012 to 31 March 2013.

The research activities of the Centre have gradually enlarged from traditional liquid crystals to gels, ferrogels, polymers, nanomaterials, nanoweeds, graphene, graphene oxide thin films and so on. In keeping with the present international trend, the Centre's emphasis has also shifted very naturally to nanoscience, in addition to soft matter.

Bengaluru PRAVEER ASTHANA

1. INTRODUCTION

The Centre, formerly known as Centre for Liquid Crystal Research (CLCR), started 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 was brought under the administrative control of the Department of Information Technology. In the year 2003, the Centre was converted to an autonomous institution under the administrative control of the Department of Science and Technology (DST), Ministry of Science and Technology. The Centre was renamed as "Centre for Soft Matter Research (CSMR)" with effect from 1 September 2010 in order to expand the scope of its research programmes keeping in view the current international trends in research. The new name was approved by DST and the amendment was registered by the Registrar of Societies, Government of Karnataka on 28 April 2010. DST has been providing core support in the form of grant-in-aid for conducting basic and applied research in soft matter and related areas. The objective of the Centre is to focus on basic science, and to develop a bias towards technology, in line with the international trends in research on Soft Matter including liquid crystal materials.

The Centre is engaged in Research and Development (R&D) on a variety of liquid crystal materials and other soft materials like gels, polymers, membranes and so on. This is the only centre in the country devoted to Research and Development in soft matter.

The Centre has also entered into an MOU to provide technical and characterization services to Bharat Electronics Ltd., a premier industrial organization under the Ministry of Defence.

2. CORE FUNDED PROJECT

The Department of Information Technology, Govt. of India, provided funds for CLCR. The grants were received by CLCR from the Department of Information Technology up to the financial year 2002-03. From 2004 onwards CLCR has been getting grants from the Department of Science and Technology (DST), Ministry of Science & Technology. The year-wise break-up of the outlay proposed by the Centre, as per the 12th Plan document, is given below.

Table: Proposed Outlay as per the Twelfth Plan document (Rs. in Lakhs)

2012-13	2013-14	2014-15	2015-16	2016-17	Total
1044.00* (FE 560.00)	1205.00 (FE 540.00)	1393.00 (FE 600.00)	1308.00 (FE 460.00)	1267.00 (FE 380.00)	6217.00 (FE 2540.00)

* During the year 2012-13, a grant of Rs. 600 lakhs was released by DST.

3. RESERVATION AND OFFICIAL LANGUAGE

The Centre follows the national policies on Reservation and Official Language as per the rules and orders issued by the Government of India from time to time.

The Centre has one SC employee working under Group C.

HINDI DAY

The Centre observed the Hindi Divas on 10 October 2012. On this occasion, Shri Man Singh, Assistant Director (I/c), Central Hindi Teaching Scheme, Bangalore gave a lecture on the use of Rajbhasha official language website. He interacted with the CSMR members about the usage of Hindi.

To popularize usage of Hindi at CSMR, everyday a scientific word is displayed on the Notice Board under "आज का शब्द".

Shri Man Singh talking on the importance of Rajbhasha official language, Hindi.

4. RESEARCH ADVISORY BOARD

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

1.	Prof. N. Kumar Raman Research Institute	Chairman
2.	Prof. Chandan Dasgupta 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. A. T. Kalghatgi Presently, Director (R&D), Bharat Electronics Limited	Member
7.	Prof. K. A. Suresh Centre for Soft Matter Research	Convener

5. FINANCE COMMITTEE

The fifth meeting of the Finance Committee with the following members was held on 15 February 2013.

1.	Ms. Anuradha Mitra, Joint Secretary & Financial Adviser, DST	Chairman
2.	Dr. Praveer Asthana, Acting Director, CSMR, Bengaluru	Member
3.	Prof. K. V. Ramanathan, Former Chairman, NMR Centre, Indian Institute of Science, Bengaluru	Member
4.	Dr. T. G. Ramesh, Former Head, Materials Science Division, National Aerospace Laboratories, Bengaluru	Member
5.	Prof. K. A. Suresh, Scientist of Eminence, CSMR	Invitee
6.	Shri S. Gulvady, Administrative Officer, CSMR	Invitee

6. RESEARCH AND DEVELOPMENT ACTIVITIES

6.1 *EFFECT OF A NETWORK OF FUNCTIONALIZED NANOSILICA PARTICLES ON PHASE TRANSITIONS IN A LONG-CHAIN ALKANE*

Despite a simple molecular structure, long chain n-alkanes exhibit a variety of phases, termed rotator phases, which are less ordered than a crystal (Cr) but more ordered than a melt isotropic liquid (Iso) phase. These intermediate phases consist of layered structures with three-dimensional crystalline order of the molecular centres, but without long-range orientational order, imparting a plastic nature to the state. Apart from such attractive features as surface crystallization, negative thermal compressibility, etc. they are industrially important in petroleum and lubricating industry, and also find applications as thermohydraulic microactuators. In bulk alkanes, up to five rotator phases, labelled simply R1 to R5, but exhibiting structures spanning from the hexagonal, rectangular and to the oblique lattices, are known. We have recently started a program to understand the influence of restricted geometry on the physical properties of these rotator phases, and have previously found that a prefabricated geometry with nanometer dimensions in a plane can substantially weaken the transitions between these phases, with a possibility of a tricritcal point. Now, we have created the restricted geometry employing a soft, fragile network generated using aerosil particles – 7-nm sized silica particles decorated with siloyl groups. The number of such groups on a particle can be adjusted to change the nature of the surfaces from hydrophilic to hydrophobic. The hydrogen bonding responsible for the network formation through aggregation, and agglomeration of particles can effectively confine soft matter (see Figure 1).

An important observation of the present studies, apart from the weakening of the transitions, is that both the strong first order transitions of the pure alkane, are accompanied by a subsidiary peak, albeit much weaker. With support from Xray measurements we argue that the subsidiary peaks are indeed transformations between the same phases as the corresponding main peaks, but occurring in the vicinity of the aerosil particles. Further, the nature of the corona also influences the bulk as well as the surface transitions, with the hydrophilic influence being higher on the former and the hydrophobic one on the latter.

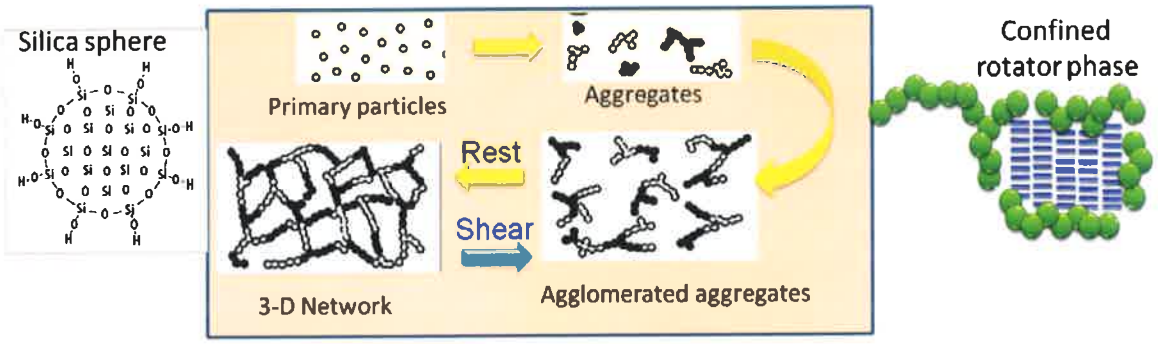


Figure 1: Silica spheres of 7 nm diameter with surfaces decorated by siloyl groups can, under right conditions, aggregate, agglomerate resulting a three-dimensional fragile network capable of confining soft matter. The nature of the particle surface can be tuned to be effectively hydrophobic or hydrophilic.

This work has been published: M. Vijay Kumar and S. Krishna Prasad, *RSC Advances*, **2**, 8531 (2012).

Investigators : M. Vijay Kumar and S. Krishna Prasad

6.2 DUAL FREQUENCY CONDUCTIVITY SWITCHING IN A CARBON NANOTUBE / LIQUID CRYSTAL COMPOSITE

In recent years blends of conducting materials in insulating hosts have been extensively investigated owing to their obvious importance from both fundamental and technological points of view. A special class of such composites are those of liquid crystals (LC) and carbon nanotubes (CNTs) being actively investigated for their extraordinary combination of high electrical conductivity of CNTs and fluid, yet anisotropic, properties of LCs. The main property of LC in such hybrid systems is their ability to get oriented by surface forces or moderate external fields. The further advantage of LC as a fluid medium would be that the external stimuli need not exert any direct influence on the CNTs at all: the LC molecules cooperatively orient the CNTs. A proper realization of such a feature has the potential to result in devices in which macroscopic properties can be switched between their anisotropic values along, say, parallel to perpendicular direction with respect to an internal reference axis. In fact, reorientation of the nematic director (average orientation direction of the LC molecules) from the equilibrium direction to that dictated by the field, and the concomitant change in the parameters such as electrical conductivity caused by the presence of CNTs, have been well demonstrated. The drawback in these systems, however, is that the return to the equilibrium value, achieved by switching the external field off, is controlled by the viscosity of the medium and thus quite slow. With a view to realize CNT/LC composites in which the return to the equilibrium state is also field-driven and thus eliminating the influence of viscosity, we have carried out studies on a composite system in which the director of the host nematic LC has the property of getting switched between two states by a mere change in the frequency of the applied field. The conductivity increases by two orders of magnitude with respect to that for the host liquid crystal, and achieves negligible temperature dependence. The frequency dependence of the ac conductivity is explained by the extended pair approximation model, although the exponent is slightly higher than generally seen. We demonstrate that the current through the sample can be field-driven between the two anisotropic values (170:1) by simply changing the frequency of the applied voltage, and exhibiting at least a millisecond response.

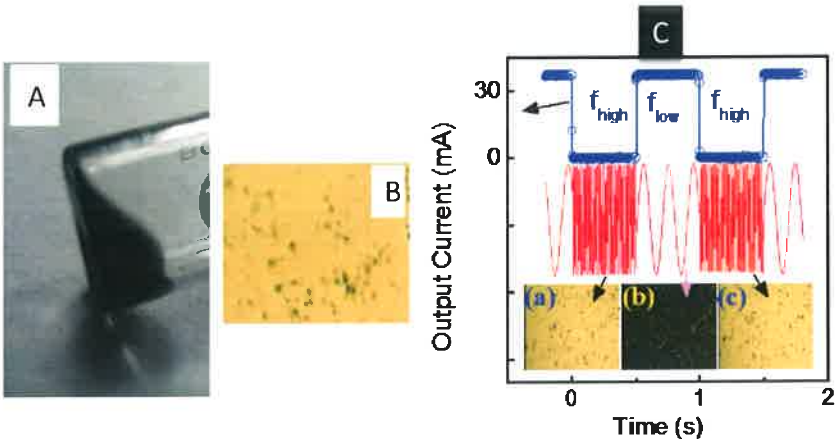


Figure : (A) Photograph of the CNT/LC composite in a vial, taken two-months after the preparation to illustrate the long-term homogenous stability of the composite. (B) Microphotograph of the field of view under a polarizing microscope, showing the random dispersion of CNT. (C) Demonstration of the CNTs composite exhibiting the dual frequency character of the conductivity switching between high and low values, when the frequency of the driving voltage of 10 V is changed from f_{low} *= 500 Hz to* f_{high} *= 600 kHz; the driving profile is shown schematically as a red line. The fact that the change in the current values is due to the reorientation of the LC molecules is illustrated in terms of the birefringent texture (a,c) at high frequency changing over to a dark field of view (b) at low frequency.*

This work has been accepted for publication: S. Krishna Prasad, M. Vijay Kumar and C.V. Yelamaggad, *Carbon (in Press).*

Investigators: S. Krishna Prasad, M. Vijay Kumar and C.V. Yelamaggad

6.3 BEND FLEXOELECTRICITY OF A POLYMORPHIC MESOGEN

Detailed temperature investigations of the bend converse flexoelectric effect on a nearly symmetrically substituted mesogen with a rich polymorphism, specifically exhibiting the nematic-smecticA (N-SmA) transition. The measurements carried out using the conoscopic method that we established recently (see inset of Figure 1) bring out the feature that the pretransitional behaviour of the flexoelectric effect on approaching the SmA phase has a quadrupolar origin (Figure 1).

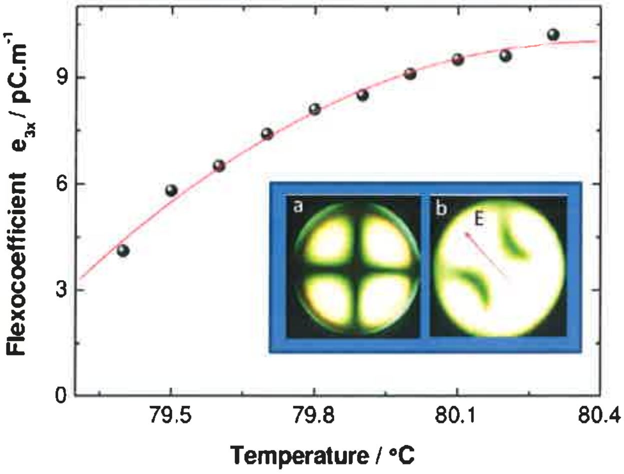


Figure 1: Bend flexoelectric coefficient e_{33} *in the nematic phase diminishing on approaching the SmA phase. The inset shows conoscopic patterns used for determining* e_{33}*: (a) in the absence of, and (b) upon application of electric field.*

This work was carried out in collaboration with Prof. A.G. Petrov of the Bulgarian Academy of Sciences, Sofia, Bulgaria. This work has been published: S. Sridevi, Uma S. Hiremath, C.V. Yelamaggad, A.G. Petrov, S. Krishna Prasad, *Bulg. J. Phys,* **39**, 3 (2012).

Investigators : S. Sridevi, Uma S. Hiremath, C.V. Yelamaggad, and S. Krishna Prasad

6.4 DESIGN OF A PPB LEVEL CHEMOSENSOR FOR PICRIC ACID

In this work on a novel pentacenequinone derivative that forms supramolecular aggregates both in bulk as well as in solution phase, the crucial structural characterization part has been carried out by us. Although in recent years several fluorescent nanofibers obtained by molecular self-assembly have been reported as sensing materials for detection of nitroaromatics, the detection of picric acid (PA) at ppb level using molecular self-assemblies remains a challenge. The present work is the first of its kind where a pentacenequinone derivative forms supra- molecular assemblies both in bulk as well as in solution phase. The columnar structures are established by Xray diffraction measurements. The self-assembling nature of the material facilitates fabrication of gel-coated paper strips to serve as a simple, portable, sensitive, fast, and low-cost method for detection of PA at extreme low levels (see Figure 1).

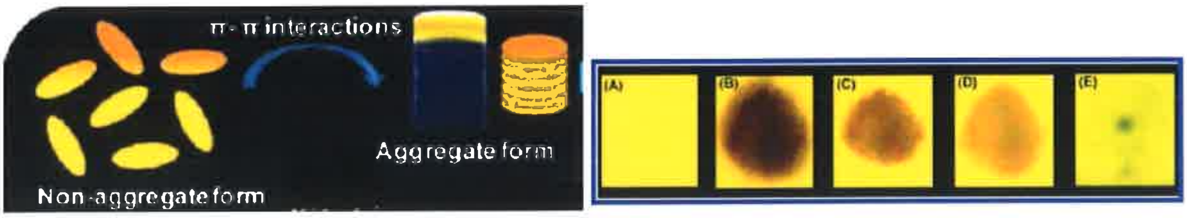


Figure 1: (Left) Aggregation of the host in its non-aggregate and aggregate forms forming the columnar structure. (Right) *Photographs (under 365 nm UV light) of fluorescence quenching of the studied organogel on test strips for the visual detection of small amount of PA (A) test strip; PA of different concentrations (B) 1 × 10^{-3} M, (C) 1 × 10^{-5} M, (D) 1 × 10^{-7} M, and (E) 1 × 10^{-9} M*

This work was carried out in collaboration with Vandana Bhalla, Akash Gupta, Manoj Kumar, Guru Nanak Dev University, Amritsar, Punjab. This work has been published: Vandana Bhalla, Akash Gupta, Manoj Kumar, D.S. Shankar Rao and S. Krishna Prasad, *ACS Appl. Mater. Interfaces*, **5,** 672 (2013).

Investigators: D.S. Shankar Rao and S. Krishna Prasad

6.5 ANCHORING TRANSITION INDUCED BY GELATION IN A LIQUID CRYSTAL SYSTEM

Realizing preferential alignment or anchoring of liquid crystalline (LC) molecules at surfaces is of fundamental importance for electro-optic applications of LC devices. The anchoring of the LC director, achieved usually by mechanical, chemical or photo-treatment of a deposited thin chemical layer on the substrate, can be parallel (planar), orthogonal (homeotropic) or tilted with respect to the surface. The anchoring can also be caused by interfaces, such as the LC-air, or LC-polymer fibre interfaces. While the general aim for applications is to retain the achieved anchoring over the entire temperature range of operation of the device, a change in the direction of the anchoring - referred to as anchoring transition (ANT) - has been known to be driven by temperature or concentration of the material and vis-a-vis interaction with the bounding surface. Especially interesting among the ways to obtain the anchoring transitions, are those driven by the nature of the polymer surface, owing to the fact that more often than not such surfaces are employed to achieve the preferential alignment of the molecules.

In this work we demonstrate a new pathway to realize an abrupt ANT triggered by gelation of a nematic liquid crystal (NLC) with an organic gelator. The anchoring transition leads to an anomalous behaviour of the dielectric permittivity for certain concentrations of the NLC-organogelator composites. X-ray studies showing a concomitant increase in the smectic-like correlation length, suggest that the change in the anchoring condition is caused by the ability of the gel fibres to orient the molecules in the nematic sol-like weak gel phase sandwiched between the isotropic (Iso) and a strong nematic gel phases, with the differentiation between the weak and strong gels evident from rheological measurements.

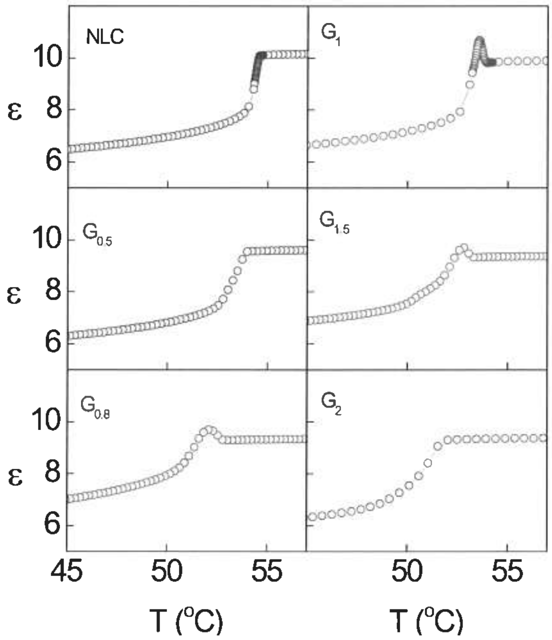


Figure 1 : Thermal variation of the permittivity obtained in the cooling mode for nematic liquid crystal (NLC) and nematic gels, G_x where x is the weight percentage of the organogelator in NLC. While NLC, $G_{0.5}$ and G_2 behave in the normal fashion with a monotonic decrease in the value at T_{NI}, anomalous behavior with a peak-like feature near TNI is observed for $G_{0.8}$, G_1 and $G_{1.5}$ composites.

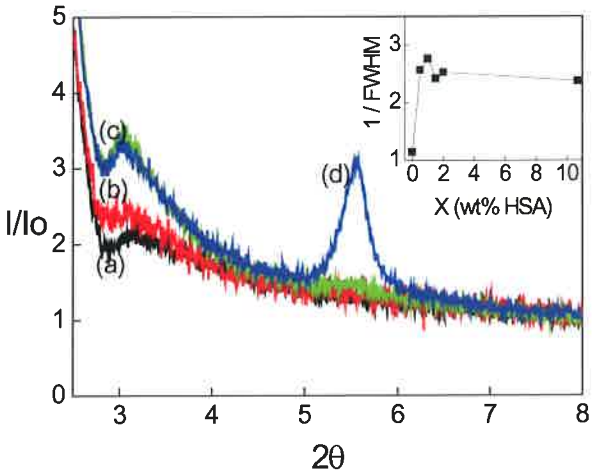


Figure 2: Small angle Xray diffraction profiles showing that the broad and weak peaks of the NLC (a, black line) and $G_{0.5}$ composite (b, red line), become stronger and better defined for the higher concentration composites G_1 and G_{10} represented by green and blue lines respectively (c). The inverse of the full width-at-half maximum (FWHM) of the peak, a measure of the short-range smectic-like order of the medium increases with increasing concentration of gelator, as shown in the inset. The peak marked (d) is due to the ordering of the gelator fibres, which is very weak for lower concentration composites but very clear for the G_{10} composite. For convenience of representation the scattering intensity (I) is normalized with respect to its value at $2\theta = 8^o$.

The observation of anchoring transitions driven by the presence of gel fibres assumes significance due to the possibility to control the sol-gel transition temperature and therefore

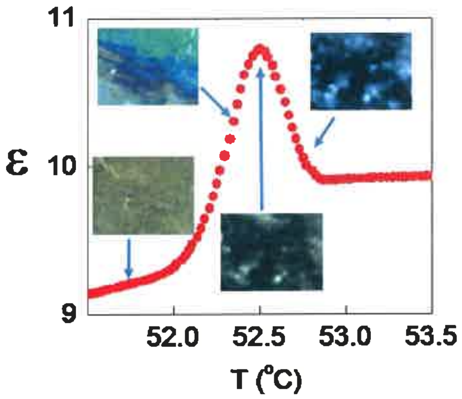


Figure 3 : A novel type of anchoring transition (ANT) in a nematic liquid crystal driven by the physical gelation of the system, manifesting as an anomaly in permittivity as well as textural changes, is described. Occurring in weak gel situations only this phenomenon appears to be driven by the ability of the gel fibres to compete with the substrate driven orientation condition.

the processing temperature of memory devices which can be fabricated employing this principle.

This work has been published: R. Bhargavi, Geetha G. Nair, and S. Krishna Prasad, *Chem Phys Chem* **14**, 331 (2013).

Investigators: Geetha G. Nair, R. Bhargavi and S. Krishna Prasad

6.6 DIELECTRIC AND SPONTANEOUS POLARIZATION STUDIES IN A FERROELECTRIC LIQUID CRYSTAL GEL

Physical gels formed by incorporation of an organogelator in a nematic liquid crystal are well studied systems. However, not much is known about the influence of such gelation on ferroelectric liquid crystals (FLCs).

Here we describe experimental investigations on the dielectric and electric switching studies in a FLC exhibiting high value of polarisation, and gelated using a low molecular weight gelator. Structural and thermal measurements clearly indicate the formation of gel structure in the smectic state. The most salient feature of the study is that the chiral smectic gel formed due to the hydrogen bonding of a small molecule gelator strongly influences the dielectric parameters of the collective relaxations as well as the electrical switching characters including the magnitude of polarization. Specifically there is a large reduction in the strength of the Goldstone (GM) mode, with a concomitant increase in its relaxation frequency. Similarly, magnitude of the spontaneous polarisation decreases by a factor of ~ 2 for the gel in comparison to the material without the gelator. For higher concentrations of the gelator an additional relaxation mode is seen which is modelled to be arising from the FLC molecules anchored to the gel network. Comparison between the optical and Xray tilt angle for the non-gel and gel materials are also being investigated.

Investigators : Geetha G. Nair, Vimala S. and S.Krishna Prasad.

6.7 OBSERVATION OF CHIRAL SMECTIC C PHASE OVER WIDE THERMAL RANGE WITH NOVEL PHASE SEQUENCES IN RIGID, BULKY CHIRAL DIMERS

Polarising optical microscopy, differential scanning calorimetry, electrical switching and X-ray diffraction studies have been carried out on non-symmetric, optically active, liquid crystal dimers in which cholesterol and three-ring salicylaldimine mesogenic cores are interlinked through a flexible even-parity (ω-oxyalkanoyloxy) spacer. All the dimers, which differ from each other in the lengths of the central spacers ($n = 3$ and 5) and the terminal alkoxy chains ($m = 20$ and 22), exhibit thermodynamically stable chiral smectic C phase over an unprecedented (100 -180 °C) thermal range.

Especially, the electrical switching study suggests the ferrielectric nature of chiral smectic C phase originating possibly due to equally strong competition between ferroelectric and antiferroelectric orderings. The occurrence of such a mesophase in these dimers is remarkable as they contain a bulky, rigid cholesterol entity.

The manuscript describing the above findings is accepted for publication in *Journal of Materials Chemistry.*

Investigators : Geetha G. Nair, Uma S. Hiremath, S. Krishna Prasad, D.S. Shankar Rao and Halley M. Menezes

6.8 PROTON AND ALPHA PARTICLE INDUCED CHANGES IN THERMAL AND MECHANICAL PROPERTIES OF LEXAN POLYCARBONATE

Thermal and mechanical properties of the Lexan polycarbonate (PC) films after the effect of 15 MeV proton and 40 MeV alpha particles irradiation were studied. There is a decrease seen the viscoelastic parameters, the storage and loss modulii, viz., G' and G" after the irradiation. The changes in the thermal and mechanical properties may be due to chain scission in PC after irradiation.

A paper describing these results is accepted for publication in the journal Vaccum.

This work was carried out in collaboration with Dr. Ganesh Sanjeev and Mr. K. Hareesh of Microtron Centre, Department of Studies in Physics, Mangalore University, Mangalagangotri 574199.

Investigators : Geetha G. Nair and R. Bhargavi.

6.9 EFFECT OF PRESSURE ON THE DIELECTRIC BEHAVIOR OF A BENT-CORE LIQUID CRYSTAL

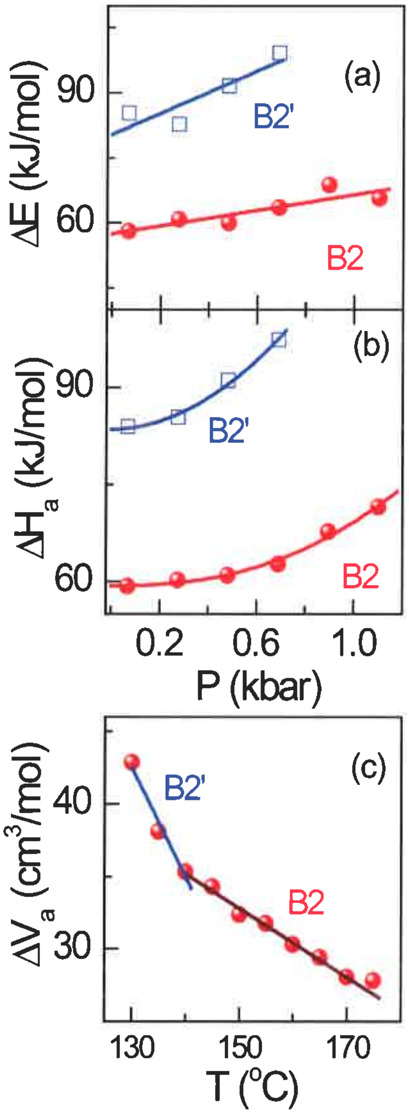


Figure 1: (a) and (b): Pressure variation of the activation energy ΔE *and activation enthalpy* ΔH_a*. Panel (c) shows the thermal variation of the activation volume* ΔV_a*.* ΔE *and* ΔH_a *increase with increase in P, the values being higher for B2′ phase than B2. (Solid lines in (a) and (b) are merely guide to the eye). The* ΔV_a *values increase with decrease in T in the two phases, exhibiting a slope change at B2-B2′ transition, as indicated by the straight lines drawn through the data.*

Mesophases formed by bent-core molecules add variety to the lamellar and columnar liquid crystal (LC) phases known from calamitic and disk-shaped molecules. Apart from the nematic phase, the relatively young class of bent-core or banana-shaped LC materials exhibit eight different phases, labeled simply B1, B2, . . .B8. Owing to their special shape, the bent-core molecules favor packing into lamellar structures with a tendency to exhibit the attractive in-plane polar order. The most studied of these is the B2 phase, which is seen with molecules having relatively long aliphatic chains that support the segregation of central aromatic cores and the terminal alkyl chains. This phase has been shown to have molecules tilted with respect to the layer normal, exhibit a polar order in the layer plane, and display an antiferroelectric arrangement in the neighboring layers. Although numerous experiments have been made on the banana mesophases at atmospheric pressure, there are hardly any at elevated pressures, and none reporting the dielectric behavior. We present dielectric spectroscopy measurements on the B2 phase at elevated pressures. The salient features of the work are (i) the dielectric studies show the presence of an additional mesophase below the B2 phase, which we show using calorimetric and x-ray studies at atmospheric pressure to be a variant of the B2 phase; (ii) at a fixed temperature, the relaxation frequency decreases with a concomitant increase in the strength of the mode, as the pressure is increased. Based on the alignment condition of the molecules and the frequency range of the mode, we assign the relaxation to be due to the rotation around the long molecular axis; and (iii) the dielectric anisotropy at a constant temperature away from the isotropic phase is hardly influenced by pressure, indicating pressure independence of the orientational order of the phase. Employing the dependence of the relaxation frequency along isobaric as well as isothermal paths, different activation parameters (see Fig 1) are determined and their behavior is compared with those of rod like systems. The values of ΔH_a are comparable to those obtained for director relaxation in rod like nematic and smectic phases, the ΔV_a values are much lower. The different behavior for the presently studied bent-core compound may be ascribed to the shape, the presence of transverse dipole moments in the molecule. More studies on bent-core molecules as well on rod like molecules with transverse dipole moments should be able to throw more light on this feature. Fixed frequency permittivity as well as frequency dependent measurements have also been carried out at atmospheric pressure as a function of DC bias. These measurements bring out the antiferroelectric character of the phase.

This work has been accepted for publication : Prasad N. Bapat, D. S. Shankar Rao, S. Krishna Prasad, U. S. Hiremath, and C. V. Yelamaggad, *Physical Review E* (in press).

Investigators: D. S. Shankar Rao, S. Krishna Prasad, Prasad N. Bapat, U. S. Hiremath, and C. V. Yelamaggad

6.10 EFFECT OF HYDROSTATIC PRESSURE ON THE FRANK SPLAY AND BEND ELASTIC CONSTANTS

The deformations of nematic liquid crystal director are governed by three principal Frank elastic constants, splay (K_1), twist(K_2) and bend(K_3). We report the first systematic work on the effect of hydrostatic pressure on the splay and bend elastic constants of a nematic (N) liquid crystal. We employed the electric field driven Freedericksz transition of a planar oriented sample to determine the elastic constants. Owing to the positive dielectric anisotropy of the sample, application of an electric field normal to the substrate, will, above a well defined threshold voltage, V_{th}, reorient the molecules from the planar to the homeotropic orientation. Using the values of V_{th} and $\Delta\varepsilon$, the elastic constant K_1 was calculated. Its dependence on T_{red}=(T-T_{NA}) at different pressures is shown in Fig. 1. K_1 has a weak dependence on temperature (except close to the isotropic phase), remain finite even in the SmA phase and therefore doesnot show any drastic variation in the vicinity of the N–SmA transition. Although the weak dependence is largely true, a slightly stronger variation is seen in the immediate vicinity of the N–SmA transition, especially at higher pressures. The compound employed here – 8OCB – has a partial bilayer phase, the anomaly is be observed only very close to the transition. This is indeed true at low pressures. But at the highest pressure studied here, the increase is in the range of ~10% which is not very different from that seen for a material with a monolayer SmA phase. Based on the results we argue that the nature of the underlying smectic phase may not be the only criterion for the observed anomalous increase in K_1. The increase of K1 with pressure (at a constant T_{red}) must be entirely due to the effect of pressure and not owing to the increase in the N range at higher P. Fig. 2 shows the temperature dependence [T_{red}=(T-T_{NA})} of K_3 for various applied pressures, exhibiting clear enhancement of the value as P is increased. In fact, at a fixed T_{red}, K_3 increases linearly with pressure at a rate of 8.7 ± 1.1 pN/kbar, which is 1.5 times larger than that for K_1 at a fixed T_{red}. The magnitude of increase in the K_3 value upon approaching the N–SmA transition increases as P increases, with the enhancement being quite large at the highest pressure studied. Unlike the splay, the bend elastic deformation is not permitted in the SmA phase since it violates the fundamental criterion of the smectic phase that the layer thickness should be kept intact. Owing to this criterion, on lowering the temperature from the N phase, the K_3 value diverges on approaching the transition. The feature that the divergence starts earlier for the high pressure set of data, indicates that the critical behaviour becomes stronger with increasing pressure.

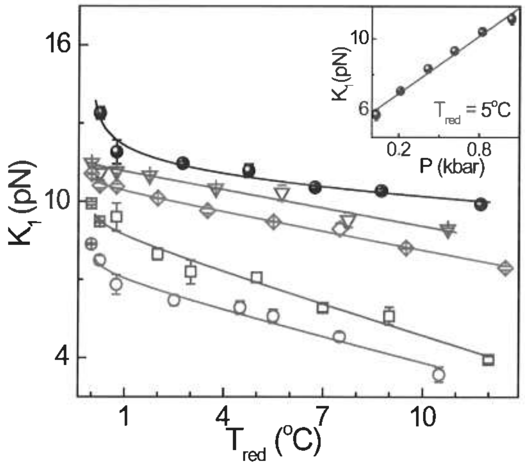


Figure 1: Diagram to show that the splay elastic constant (K_1) for the compound 8OCB increases with decreasing T_{red} and increasing P. The data shown are for P = 0.04 kbar, 0.21 kbar, 0.61 kbar, 0.82 kbar and 1.04 kbar. The linear increase of K_1 with P at a fixed T_{red} value is depicted in the inset.

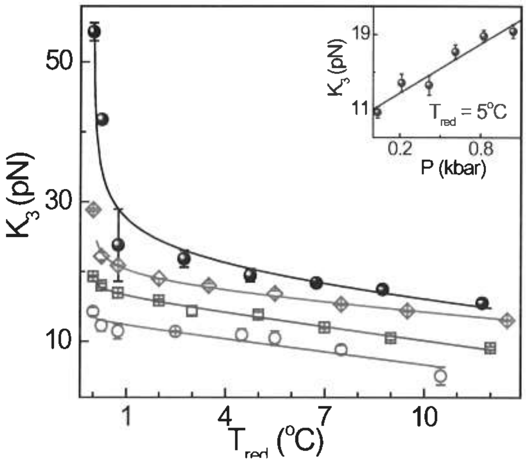


Figure 2 : Behaviour of the bend elastic constant (K_3) as a function of reduced temperature for the compound 8OCB at pressures, P = 0.04 kbar, 0.21 kbar, 0.61 kbar, and 1.04 kbar. Note the large increase in the value in the vicinity of T_{red} = 0 for the highest pressure set. The bend elastic constant increases linearly with pressure at T_{red} values not too close to the transition to the SmA phase, as shown in the inset.

Since with increasing P the range of the N phase increases, this should be the reason for the observation.

This work has been published : Prasad N. Bapat, D.S. Shankar Rao, S. Krishna Prasad and Uma S. Hiremath, *Thermochimica Acta,* **537**, 65 (2012)

Investigators: D. S. Shankar Rao, S. Krishna Prasad, Prasad N. Bapat, U. S. Hiremath

6.11 XRAY INVESTIGATIONS ON HEKATES-TRIS(N-SALICYLIDENEANILINE)S SYSTEM

XRD measurements has been carried out on six and nine peripheral n-alkoxy tails of a photoluminescent starshaped discotic liquid crystals (TSANs). These series of discotics with six and nine peripheral n-alkoxy tails were especially designed and accomplished to understand the relation between mesomorphic/photophysical properties and molecular structure. Figure 1 shows XRD measurements on dialkoxy TSANs (DLT - 10) for the high (150 °C; red trace) and low (100 °C; blue trace) temperature phase. The high-temperature (HT) diffraction pattern comprised a set of sharp reflections in the low-angle region besides two diffuse peaks at about 4.6 and 3.4 Å at high angles. The sharp peaks are indexed as the (100), (200), and (3−20) diffractions of a 2D hexagonal lattice with an intercolumnar distance of about 42.2Å. As can be seen in Figure 1b (blue trace), the low-temperature (LT) Col phase possesses nearly a matching XRD data, of course with some marginal changes in spacing values, to that of the HT columnar (Colh) phase. But in the wake of POM and DSC studies clearly indicating the occurrence of two Col phases the low temperature phase is indexed to a columnar phase with a rectangular lattice. This phase freezes into a glassy state near room temperature (RT) and remains unaltered until −60 °C. XRD pattern of TLT06 (trialkoxy long-armed TSANs) plotted in Figure 2 shows low angle reflections with spacings, viz., 32.91, 30.77, 26.13, 16.41, 12.36, and

10.92 Å which were assigned to (100), (010), (110), (200), (220), and (300) diffractions. These

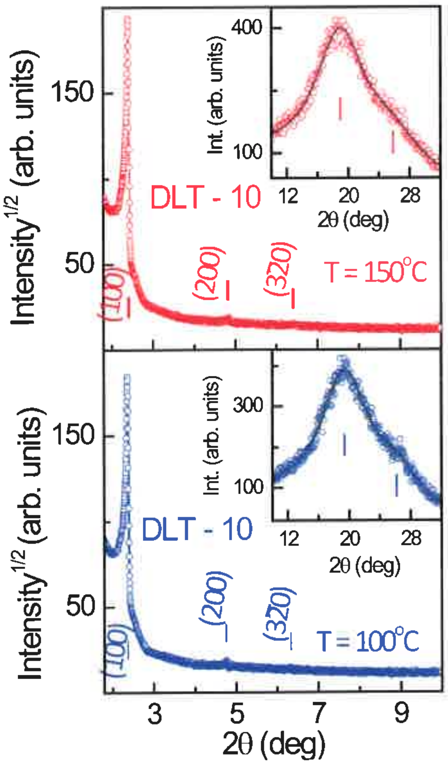


Figure 1: XRD profiles depicting the intensity against the 2ϑ obtained for the Col phases of compounds DLT-10. The insets show the diffuse profile in the wide-angle region that could be fit (solid line) to two Lorentzian peaks arising from short-range correlations between the alkyl chains (h_a), and between the cores (h_c) within a single column. Note that peak positions are indicated by solid lines.

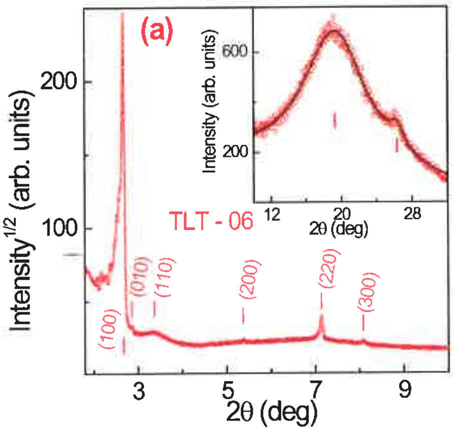


Figure 2: One dimensional XRD profiles plotting the diffraction intensity against the 2ϑ obtained for the Col phase of compound TLT-6

reflections could be indexed to oblique columnar phase (Col$_{ob}$) with the following unit cell parameters: a = 33.40 Å, b = 31.25 Å, and column tilt angle γ = 79.9°.

This work has been published : A. S. Achalkumar, U. S. Hiremath, D. S. Shankar Rao, S. Krishna Prasad and C V. Yelamaggad, *J. Org. Chem.*, **78**(2), 527 (2013).

Investigators: D. S. Shankar Rao, S.Krishna Prasad, C.V. Yelamaggad, U.S. Hiremath

6.12 INFLUENCE OF THE CHLORO SUBSTITUENT ON THE MESOMORPHISM OF UNSYMMETRICAL ACHIRAL FOUR-RING BENTCORE COMPOUNDS

(a) XRD measurements were carried out on the B7 mesophase for the chloro substituted achiral unsymmetrical four-ring banana-shaped molecules. Representative diffractograms

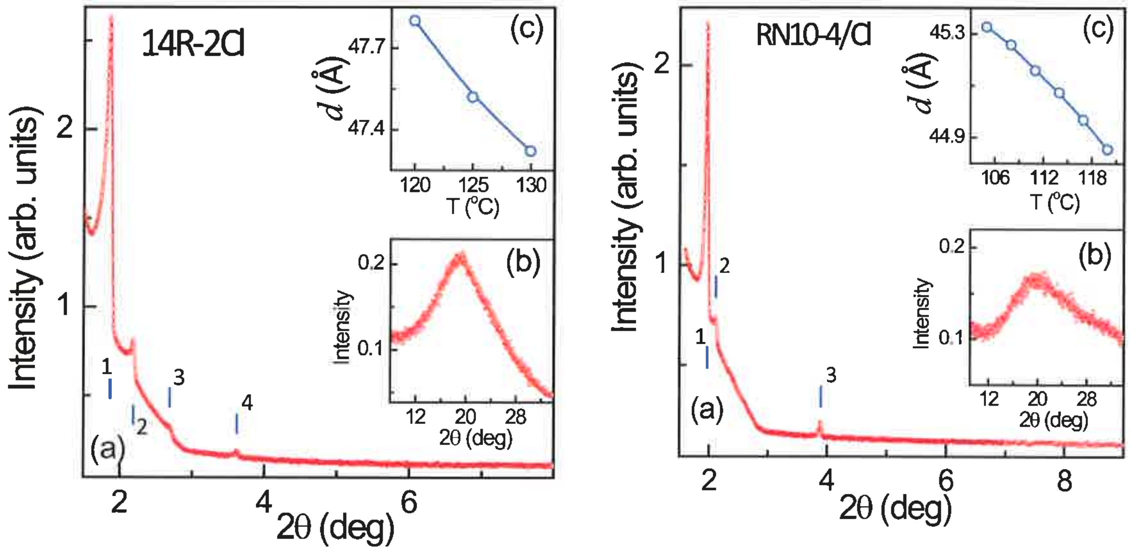


Figure 1 (a) Intensity versus 2θ profile in the low angle region for the compound 14R-2Cl (Left panel) at T = 130°C and 10R-4Cl (Right panel) at T = 120 °C in the B7 mesophase. Inset (b) shows the diffuse peak in the high angle region reflecting the liquid-like ordering of the layers. Inset (c) shows the thermal variation of layer spacing d in the mesophase for the two compounds. The solid line serves as a guide for the eye.

(intensity versus 2θ profile) in the mesophase at 130°C are shown in Fig. 1 for the two compounds. The broad diffuse peak in the high angle region (inset (b)), corresponding to a spacing of 4.61 °A (14R-2Cl), 4.41 °A (RN10-4Cl), together with the sharp intense reflections in the low angle region, establishes the layering order of the mesophase. There are four sharp peaks in the low angle region for 14R-2Cl and three for RN10-4Cl. The low angle intense sharp peak corresponds to layer periodicity. This spacing is lower than the calculated molecular length suggesting that the molecules are tilted in the layer with the amount of tilt angle being 33° and 19° deg for the compounds 14R-2Cl and RN10-4Cl respectively. All low angle peaks can be indexed to a rectangular lattice which indicates that the molecules are arranged in a two-dimensional (2D) lattice within the layer. Inset (c) shows thermal variation of the layer spacing (d) for the compound. The spacing d increases with decreasing temperature in the B7 phase with extracted slope dd/dT values being = - 4.8 x 10^{-2} °A K^{-1} for the compound 14R-2Cl and - 3.14 x 10^{-2} °A K^{-1} for the compound RN10-4Cl. The negative thermal expansion is due to the stretching of the alkyl chains with a decrease in temperature. Another reflection in the low angle region (at $2\theta \sim 1.26^{\circ}$) indicative of in-plane modulation of the smectic layers of wavelength $\lambda \sim 70.1$ °A associated with the 2D polarization splay modulated layer undulated structure, a structural feature associated with the $B7/B1_{RevTilted}$ phases with a 2D lattice.

This work was carried out in collaboration with Prof. N.V.S Rao, Chemistry Department, Assam University, Silchar.

This work has been published : R. K. Nath, R. Deb, N. Chakraborty, G. Mohiuddin, D. S. Shankar Rao and N.V.S. Rao, *J. Mater. Chem. C*, **1**, 663 (2013).

Investigator: D. S. Shankar Rao

(b) X-Ray investigations carried out on unsymmetrical tetracatenar system has revealed it to be a smectic A phase of type monolayer where layerspacing d ~ l (length of the molecule). In another investigations on unsymmetrical oxadiazole unit showed interesting phase sequence viz., showing either SmC*–SmA–TGB–N*–BP or SmC*–SmA. In the materials with oxadiazole-based non-symmetric trimers terminating with ferrocene and cholesterol units showed TGBC*-N*-BP or TGBC*-N* phase sequence revealed by XRD studies.

This work was carried out in collaboration with Prof K.C. Majumdar, Department of Chemistry, University of Kalyani, West Bengal.

This work has been published : K.C. Majumdar P.K. Shyam, D.S. Shankar Rao and S. Krishna Prasad, *Liq.Cryst.*, 39, 1117 (2012); K.C. Majumdar, P. K. Shyam, D.S. Shankar Rao and

S. Krishna Prasad, *Liq.Cryst.,* 39, 1358 (2012); A. S. Achalkumar, U. S. Hiremath, D. S. Shankar Rao, S. Krishna Prasad and C V. Yelamaggad, *Liq Cryst.,* 40, 305 (2013).

Investigators: D. S. Shankar Rao and S. Krishna Prasad

6.13 ACHIRAL BENT-CORE AZO COMPOUNDS

Azo functionalized materials are of special interest due to their photo-sensitive nature, which can be exploited for optical and optoelectronic devices. From this point of view, we have been working on different types of azo substituted liquid crystalline materials and the first azo substituted achiral bent-core liquid crystals are reported by our group in 2001. Since then, we have synthesized several new photochromic bent-core materials and studied the photo-induced effects in such systems.

During the above mentioned period we performed a study on the effect of different types of linkage groups and their direction of linking on liquid crystalline properties in such compounds. Thus, we synthesized and studied six new homologous series of azo substituted achiral bent-core compounds. The molecular structures of these compounds are characterized by organic spectroscopic methods. The liquid crystalline properties are studied using polarizing optical microscopy, differential scanning calorimetry, X-ray diffraction and electro-optical studies. We observed a variety of mesophases in these compounds, viz., N, B_1, B_2, SmA, SmA_dP_A etc. From our investigations, we found that the type and the direction of the linkage groups affects the thermal range and sometimes, even the nature of the mesophase itself. We carried out photo-induced studies in the B_2 mesophase of some of the selected compounds and found that the reversal in the direction of linkage groups does affect the photochromic properties of the compounds. The photo-induced phenomenon observed for one of the compounds 4e, during the polarizing optical microscopy is illustrated in the following figure.

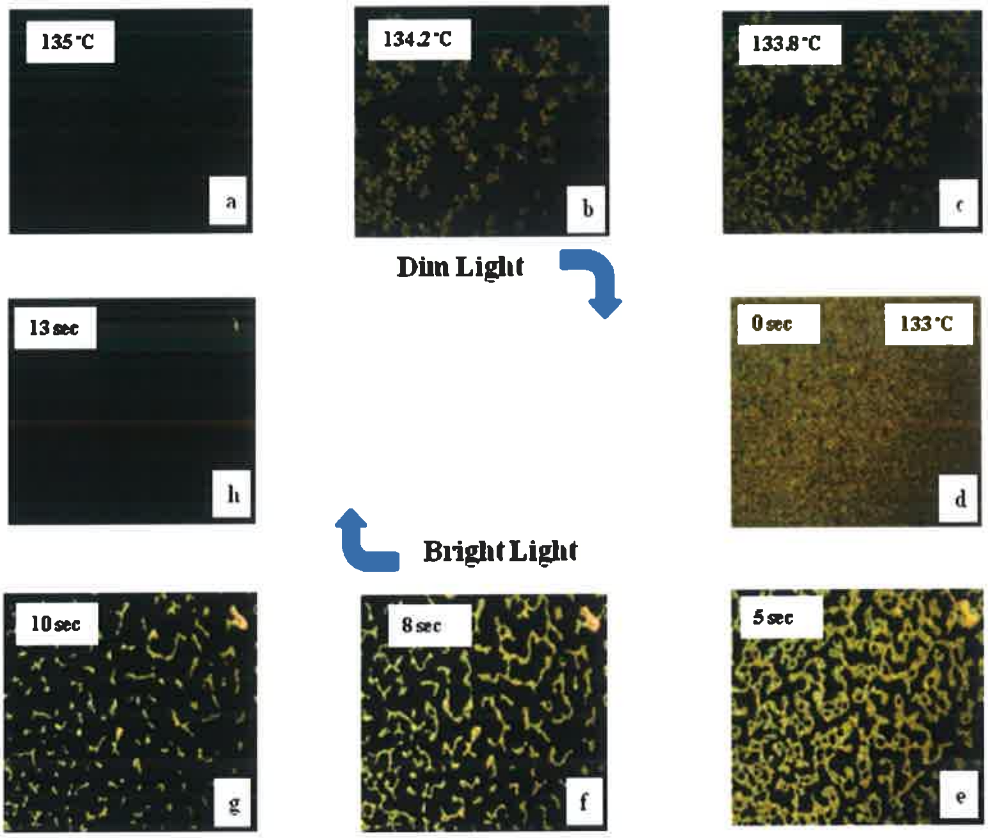


Figure: POM textures of the compound 4e: (a) isotropic phase. (b), (c) and (d) show stepwise formation of the B_2 mesophase on cooling (a) with dim light. (e) – (h) show the disappearance of (d) on increasing the light intensity at constant temperature (133°C).

This work was carried out in collaboration with Arun Roy, Raman Research Institute, Bangalore.

This work has been published: N.G. Nagaveni, Arun Roy and Veena Prasad, *J. Mater. Chem.*, **22**, 8948 (2012).

Investigators: N.G. Nagaveni and Veena Prasad

6.14 BENT-CORE NEMATIC LIQUID CRYSTALS

The nematic liquid crystals formed by bent-core compounds are of interest due to their unusual properties when compared with the nematic liquid crystals composed of rod-like molecules. Thus, we have been working on such materials and observed a nematic to nematic phase transition in one of our bent-core compounds, viz., A131. Earlier, we had undertaken XRD and Carbon-13 NMR study of this compound to confirm this phase transition and from the results obtained, we proposed that there is a uniaxial to the biaxial nematic phase transition in this material.

During the above mentioned period, we undertook a study of the proton NMR spin-lattice relaxation time, T_1, of the compound A131 as a function of temperature and Larmor frequency, using a combination of fast field-cycling and standard NMR techniques. The experimental results clearly show a transition within the nematic range of this compound, previously identified as one from the uniaxial to the biaxial nematic phase.

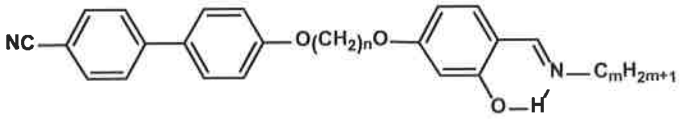
This work was carried out in collaboration with A. Aluculesei, C. Cruz, P.J. Sebastiao, Technical University of Lisbon, Lisbon, Portugal; F. Vaca Chavez, Centro de Fisica da Materia Condensada, Lisbon, Portugal and R.Y. Dong, University of British Columbia, Vancouver, Canada.

This work has been published : A. Aluculesei, F. Vaca Chavez, C. Cruz, P. J. Sebastiao, N. G. Nagaveni, Veena Prasad and R. Y. Dong, *J. Phys. Chem. B*, **116**, 9556 (2012).

Investigators: N.G. Nagaveni and Veena Prasad

6.15 REENTRANT NEMATIC PHENOMENON IN NOVEL DIMER-LIKE LIQUID CRYSTALS

Dimer-like liquid crystals (LCs) comprising cyanobiphenyl and *N*-(*n*-alkyl)salicyl-aldimine segments interlinked via a flexible spacer of varying length and parity, have been synthesized and characterized thoroughly with the help several complementary studies. Among the six synthesized LCs (Chart 1), two compounds with oxyoctyloxy-nonyloxy (**DC-8,9**) and oxydecyloxy-nonyloxy (**DC-10,9**) spacer-terminal chain combination exhibit nematic (N)-smecti A-nematic (N_{re}) sequence with the nematic phase exhibiting reentrance. This existence of reentrant phenomenon in this class of mesogens, as evidence by textural pattern (Fig. 1), calorimetric (Fig. 2a) and optical transmission (Fig. 2b) studies, appears to be originating from the packing frustrations (dipolar factors).



DC-8,9: n = 8, m = 9   **DC-9,9**: n = 9, m = 9   **DC-10,9**: n = 10, m = 9
DC-8,10: n = 8, m = 10   **DC-9,10**: n = 9, m = 10   **DC-10,10**: n = 10, m = 10

Chart 1: Molecular structure of the four series of dimer-like compounds.

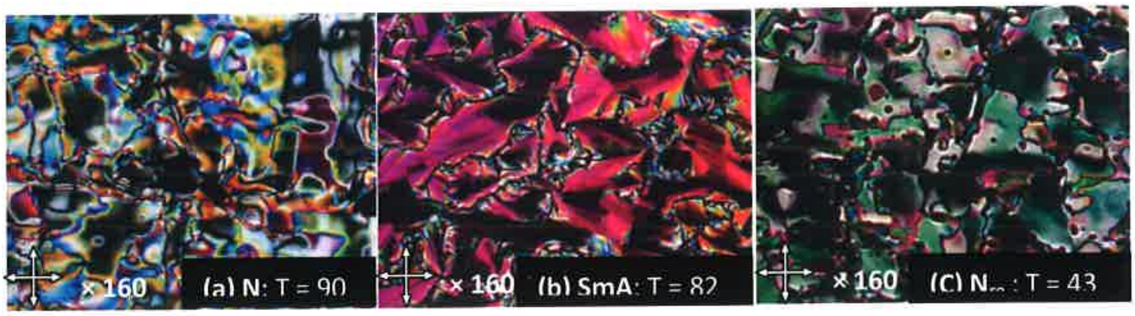


Figure 1: Photomicrographs of the three mesophases observed for planarly-aligned ***DC-10,9****: (a) nematic texture consisting of schlieren, threaded and marble patterns; (b) focal-conic texture of the SmA phase; (c) marble texture of the reentrant N phase.*

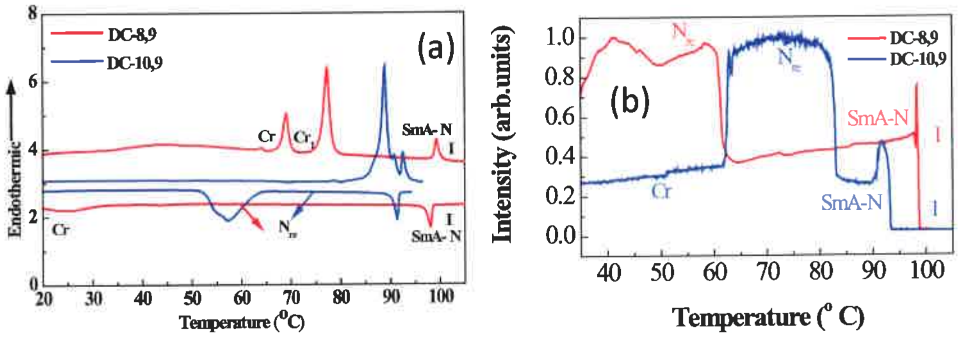


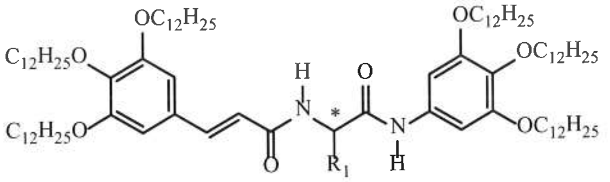
Figure 2: (a) DSC traces of the second heating and first cooling cycles recorded at a rate of 5 °C for the compounds ***DC-8,9*** *(red traces) and* ***DC-10,9*** *(blue traces). (b) The profiles of optical transmission obtained as a function of temperature for* ***DC-8,9*** *(red trace) and* ***DC-10,9*** *(blue trace)*

This work has been published: Rashmi Prabhu and C. V. Yelamaggad, *J. Phy. Chem. B*, **116,** 9549 (2012).

Investigators: Rashmi Prabhu and C. V. Yelamaggad.

6.16 SUPRAMOLECULAR, OPTICALLY ACTIVE BISAMIDES DERIVED FROM A-AMINO ACIDS

Three pairs of enantiomeric, supramolecular hexacatenar liquid crystals (LCs) (Chart 1) derived from natural α-amino acids such as L/D-alanine, L/D-leucine and L/D-valine have been evaluated systematically for their mesomorphic behaviour. They exhibit columnar (Col) phase (Fig. 1a) over a wide thermal range. Particularly, a pair of enantiomers derived from L/D-leucine residues stabilize hexagonal Col (Col$_h$) phase over a wide the temperature range of -5 $^{\circ}$C to 180 $^{\circ}$C (Fig. 1b). Circular dichroism (CD) (Fig. 2a-b) and FTIR studies suggest the chiral (helical) organization of mesogens within the columns through intermolecular H-bonding; thus, these enantiomers represent one of the rarely reported examples of LCs exhibiting supramolecular Col$_h$ phase at room temperature. The gelation studies reveal the ability of these bisamides to form stable supramolecular gels in ethanol through H-bonds.



CHAB-1 : R_1 = (*S*)-Methyl **CHAB-3** : R_1 = (*S*)-Isobutyl **CHAB-5** : R_1 = (*S*)-Isopropyl
CHAB-2 : R_1 = (*R*)-Methyl **CHAB-4** : R_1 = (*R*)-Isobutyl **CHAB-6** : R_1 = (*R*)-Isopropyl

Chart 1: Molecular structure of the three pairs of supramolecular hexacatenar LCs.

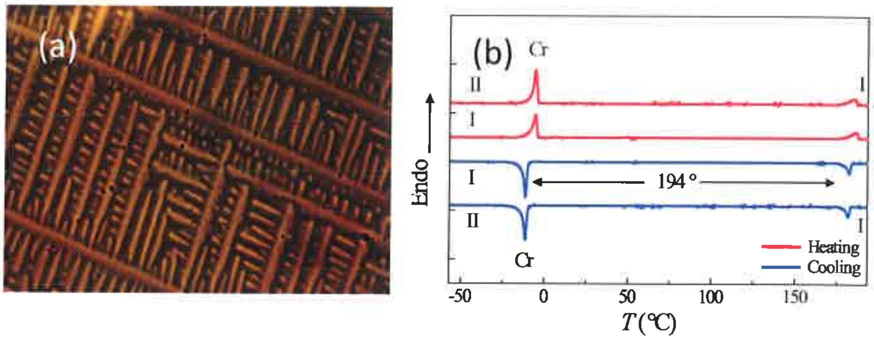


*Figure 1: (a) Microphotographs of the Col phase observed for **CHBA-3** at 179 °C. (b) DSC traces of the first and second heating-cooling cycles recorded at a rate of 5 °C for the bisamide **CHBA-3**.*

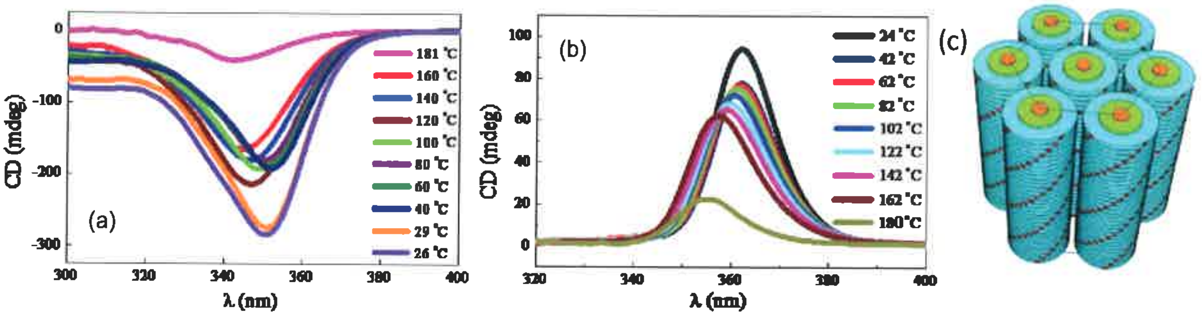


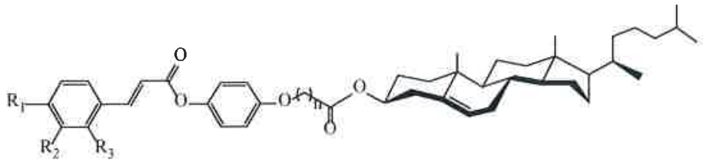
*Figure 2. The CD spectra obtained in the Col phases as a function of temperature for the enantiomeric pairs (a) **CHBA-3** and (b) **CHBA-4**. Notice that they exhibit mirror image CD curves in the mesophase. Schematic representation of the helical Col$_h$ phase formed by self-assembly of bisamides.*

This work has been published: G. Shanker, D. S. Shankar Rao, S. Krishna Prasad and C. V. Yelamaggad, *Tetrahedron*, **68,** 6528 (2012).

Investigators: G. Shanker, D. S. Shankar Rao, S. Krishna Prasad and C. V. Yelamaggad.

6.17 OCCURRENCE OF HIGHLY FRUSTRATED AND CHOLESTERIC LIQUID CRYSTAL PHASES IN DIMERS

A number of nonsymmetric, optically active, liquid crystal dimers belonging to three different series (Chart 1), have been characterized. The vast majority of them exhibit enantiotropic liquid crystal behavior involving mesophases such as chiral nematic (N*), twist gain boundary (TGB), smectic A (SmA) phases besides some unknown mesophases. Some of the dimers display TGB phase possessing chiral smectic C (SmC*) blocks, denoted as the TGBC* phase (Fig. 1a-c), over an exceptionally wide thermal range. In fact, in one of the members, the phase occurs for more than 100 °C thermal range, persisting closer to room temperature; this is remarkable given the fact that such a behavior has been scarcely reported owing to the complex and highly frustrated nature of the TGBC* phase. XRD study suggests the formation of an intercalated SmA (SmA_c) phase (Fig. 2). The phase transitional behavior shows a dependence on the length and parity of the central spacer as well as the length of the terminal tail. The odd-even effect has been prominently seen in the clearing temperatures, a feature strongly reminiscent to that observed for cholesterol-based dimers reported hitherto.



Series 1: **MDC - n, R** Series 2: **DDC - n, R** Series 3: **TDC - n, R**

Chart 1: Molecular structure of the three series of non-symmetric LC dimers.

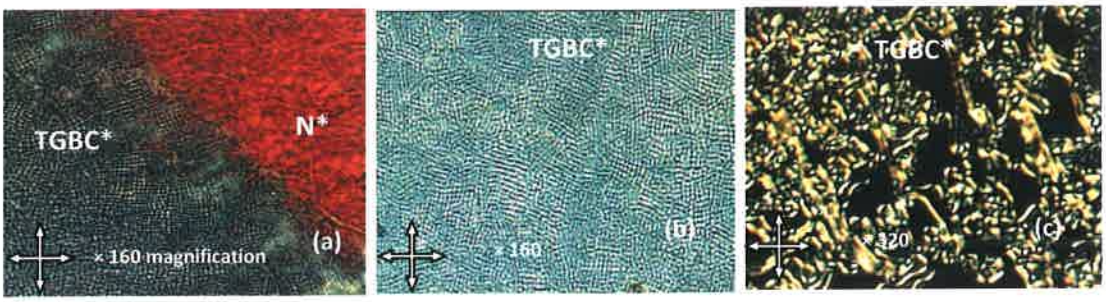


Figure 1. Photomicrographs of optical textures observed for mesophases under planar and homeotropic anchoring conditions of one of the dimers: (a) a texture showing the transformation of N phase (planar texture) to the TGBC* phase (square grid pattern), (b) square grid pattern of the TGBC* phase and (c) undulated filament texture of the TGBC* phase seen for the homeotropic alignment.*

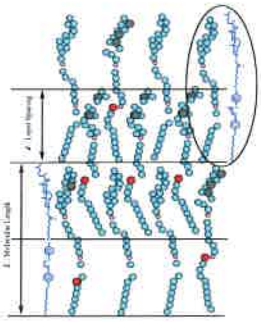


Figure 2. A schematic representation of the self-assembly of dimers into an intercalated SmA phase.

This work has been published: G. Shanker and C. V. Yelamaggad, *New J. Chem.*, **36**, 918 (2012).

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

6.18 LIGHT EMITTING, STAR-SHAPED TRIS(N-SALICYLIDENEANILINE) DISCOTIC LIQUID CRYSTALS

Star-shaped tris(*N*-salicylideneaniline) discotic liquid crystals, as shown in Chart 1, synthesized by condensing 1,3,5-triformylphloroglucinol with 4-(alkoxystyryl)benzenamines, have been examined for their thermal behaviour and photoluminescence. The novelty of these discotics stems from the fact that three stilbene fluorophores, varying in the number and length of terminal chains, are joined to an electron accepting central core. All six compounds, existing in two inseparable keto-enamine tautomeric forms featuring C_{3h} and C_s rotational symmetries, show columnar liquid crystal behaviour as ascertained unequivocally with the help of polarizing optical microscope (Fig.1a) and differential scanning calorimeter (Fig.1b). Photoluminescence property has been examined both in solution and columnar states (Fig. 2). Green light emission observed in the solution state is especially noteworthy.

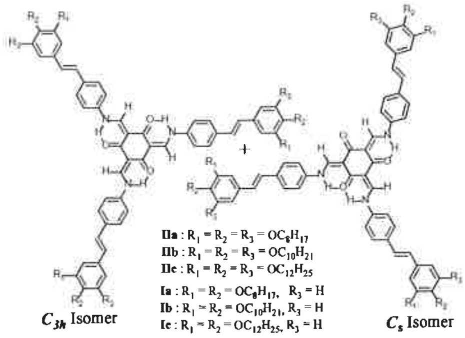


Chart 1: Molecular structure of star-shaped tris(N-salicylideneaniline) discotics.

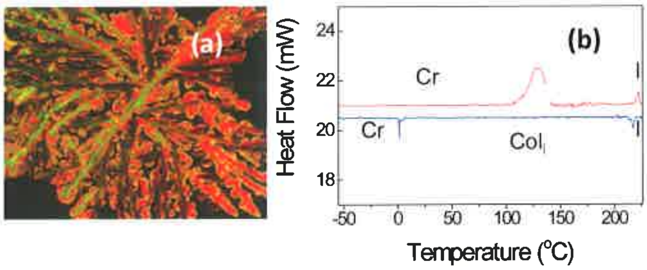


*Figure 1. (a) Microphotograph of the optical texture observed for the Col phase of **Ia** at 211 °C. (b) DSC traces of the first heating-cooling cycles obtained for **Ia**.*

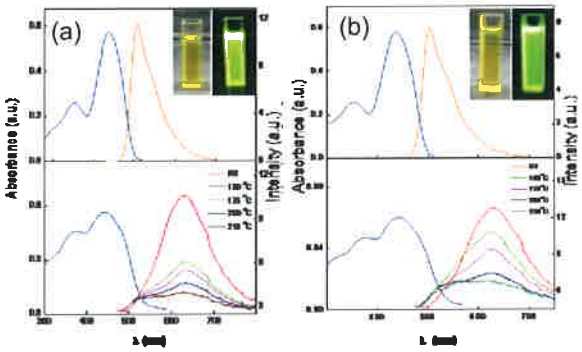


*Figure 2. UV-Vis (left peaks) and emission (right peaks) spectra of **Ia** and **IIa** in their solution (top panels) and Col phase (lower panels). Insets show the pictures of solution as seen before and after illumination with 365 nm light.*

This work has been published: A. S. Achalkumar and C. V. Yelamaggad, *Tetrahedron Letters*, **53,** 7108 (2012).

Investigators: A. S. Achalkumar and C. V. Yelamaggad.

6.19 TRIS(N-SALICYLIDENEANILINE) DISCOTICS BEARING PHENYL BENZOATE ARMS

Two series of new, photoluminescent star-shaped discotic liquid crystals with three phenyl benzoate arms, derived from tris(*N*-salicylideneaniline)s, have been characterized using X-ray scattering (Fig. 1a), polarizing optical microscopy (Fig.1b) and differential scanning calorimetry (Fig. 1c). These complementary studies suggest the presence of columnar (Col) phase in vast majority of the TSANs prepared. The 2D lattices of these fluid columnar phases were found to be characteristic of a hexagonal Col ($\mathrm{Col_h}$), a rectangular Col ($\mathrm{Col_r}$) or an oblique Col ($\mathrm{Col_{ob}}$) phases depending on the number / length of the peripheral flexible chains. The stabilization of $\mathrm{Col_{ob}}$ phase, a less commonly found fluid columnar structure, and the first of its kind in TSAN systems, implies very intensive intermolecular (face-to-face) interactions among the TSAN cores within the column. The photophysical properties were investigated both in solution and the columnar states by UV-Vis absorption and photoluminescence; markedly, the solution state emits light in the blue region.

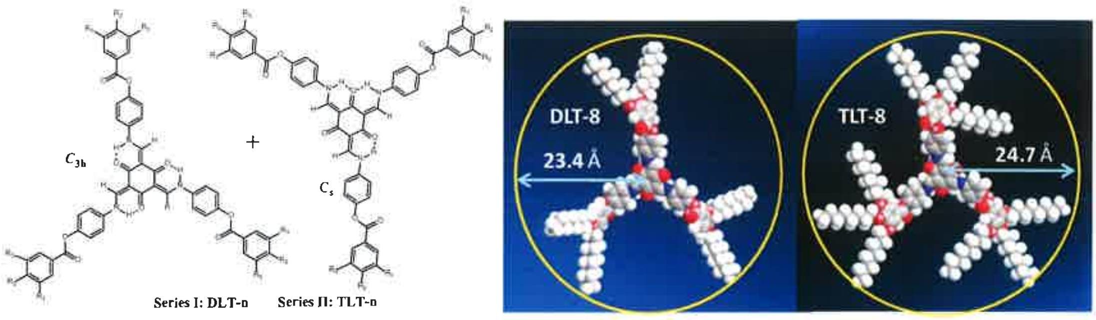


Chart 1: Right - Molecular structure of star-shaped TSAN discotic LCs characterized. Left - Space-filling energy minimized (all-trans) molecular models of TSANs

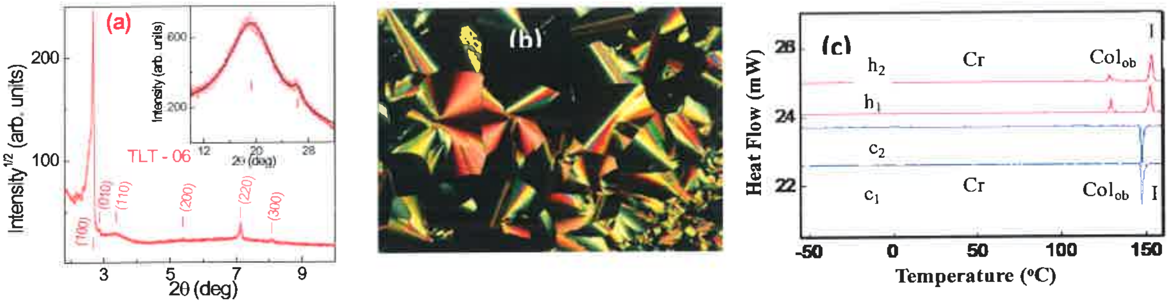


*Figure 1. (a) One-dimensional XRD profiles plotting the diffraction intensity against the 2ϑ obtained for the Col phase of compounds **TLT-6.** (b) Photomicrograph of optical texture obtained for the Col$_{ob}$ phase of **TLT-6** at 170 °C. (c) DSC traces of the first & second heating (h$_1$ and h$_2$) - cooling (c$_1$ and c$_2$) cycles of **TLT-8**.*

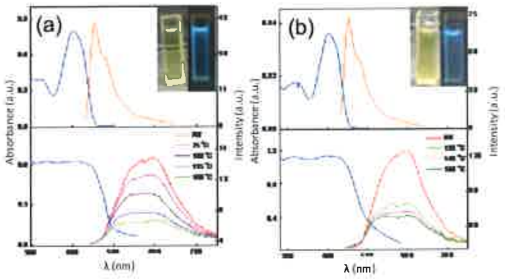


*Figure 2. Absorption and emission spectra in THF solution (top panels) and in the thin films of the mesophases (lower panels) obtained for **DLT-12** and (b) **TLT-8**.*

This work has been published: A. S. Achalkumar, Uma S. Hiremath, D. S. Shankar Rao, S. Krishna Prasad and C. V. Yelamaggad, *J. Org. Chem.*, **78**, 527 (2013).

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

6.20 METALLO-ORGANIC PHTHALOCYANINE FILMS AT AIR-WATER AND AIR-SOLID INTERFACES

Metallo-organic phthalocyanine molecules are highly conjugated macrocyclic compounds exhibiting unique electrical, magnetic and optical properties. They have excellent thermal and chemical stability. These materials are used as organic semiconductors, field effect transistors, photovoltaic and spintronic devices. We have studied thin films of metal (Ni) incorporated phthalocyanine (Pc) at the air-water interface. Surface manometry studies performed at different temperatures show that it forms a stable monolayer with a collapse pressure of about 40 mN/m and a limiting area per molecule of about 87 Å^2 at 20°C. The isotherm shifts towards lower area per molecule (A_m) with increase in temperature (Fig. 1). The inset of Fig. 1 shows a minima at a surface pressure (of 10 mN/m indicating the existence of two different phases of different elastic modulus (E). The maximum value of E is about 150 mN/m at a surface pressure of about 20 mN/m.

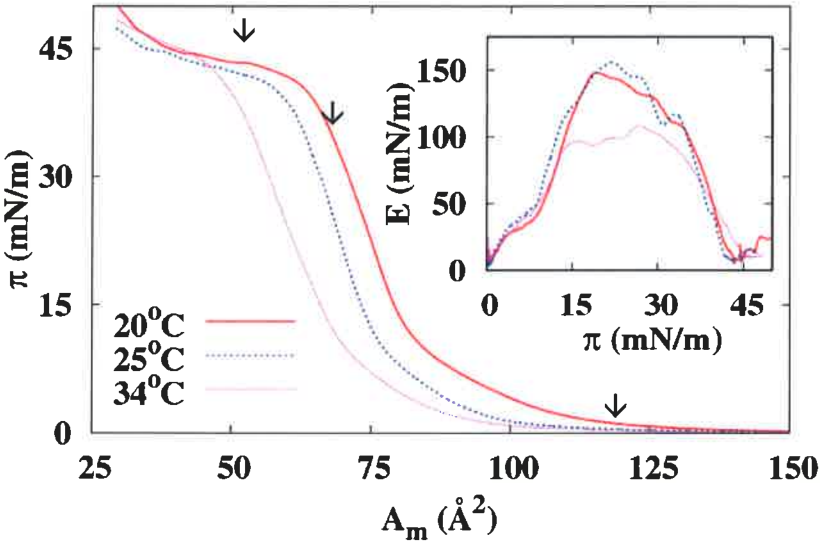


Figure 1: Surface pressure (π) – Area per molecule (A_m) isotherm for Ni-Pc at different temperatures. Arrow marks indicate the region at which the BAM images were taken. Inset shows the variation of compression elastic modulus (E) with π.

Brewster angle microscope (BAM) studies on these films provide rich information on the textures and morphology of two dimensional phases (Fig. 2). The images obtained correspond to the marked regions denoted by an arrow in the isotherm (Fig. 1). Fig. 2a shows the presence of fluid-like domains. It is transformed to solid-like phase at higher surface density (Fig. 2b). In the collapse region, bright dots appear indicating the bulk crystallites. We could successfully transfer these films onto hydrophobic silicon substrates with transfer ratio of about 1. Atomic force microscopy provides useful insights on the surface morphology of the deposited films. Figure 3a shows the topography of a 25 layer thick Ni-Pc film on silicon substrates transferred at 25 mN/m. The corresponding amplitude and phase images are shown in Figure 3b and 3c. Figure 3d shows the height profile (line drawn across Fig. 3a). The height of the film varies between 6 and 9 nm.

Figure 2: *Brewster angle microscope images of Ni-PC phthalocyanine monolayer at the air-water interface. a) Gas + L_1 phase at 120.5 Å^2, b) L_1 + S phase at 69.2 Å^2 and c) S + bulk crystallites at 50.2 Å^2 at 25 °C. Field of view: 157 x 157 µm^2.*

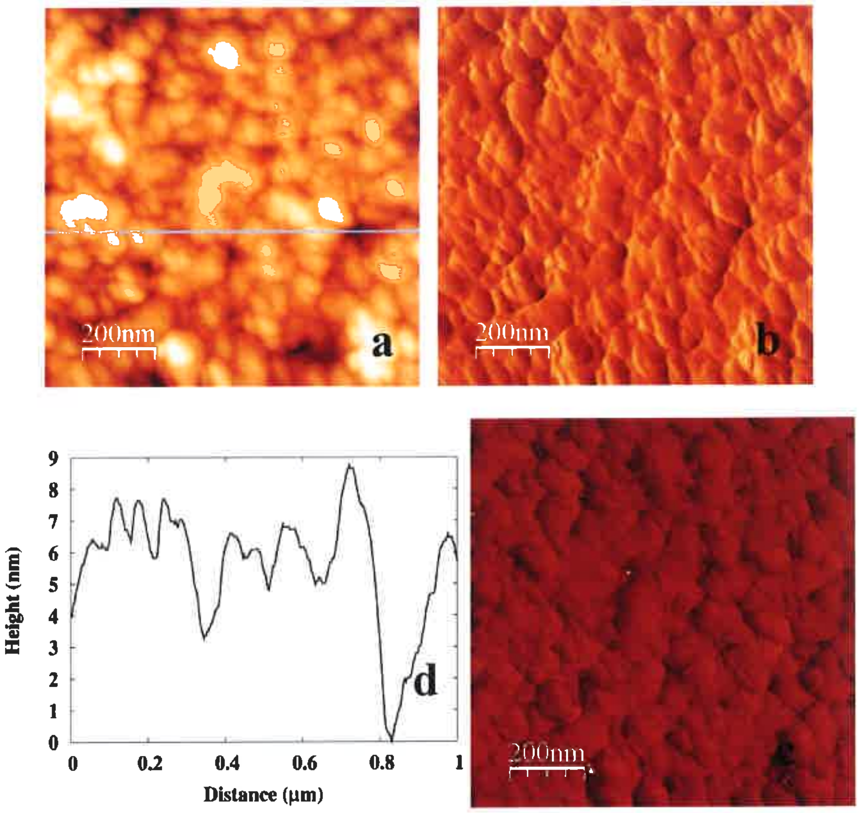


Figure 3: *a) Topography, b) Amplitude and c) Phase images obtained using AFM of 25 layers thick NiPc thin film on silicon substrates. d) Height profile (line drawn across a).*

Further studies are underway to address the surface potential and electrical properties of the transferred film.

Investigators: P. Viswanath and T. Shilpa Harish

6.21 ANISOTROPIC MAGNETORESISTANCE STUDIES OF POLYCRYSTALLINE $La_{0.67}Ca_{0.33}MnO_3$

We have synthesized polycrystalline $La_{0.67}Ca_{0.33}MnO_3$ by solid state reaction method and studied the structural, morphological, resistivity, magnetoresistance and anisotropic magnetoresistance properties of it with detailed analysis of anisotropic magnetoresistance. The X-ray diffraction study of our sample confirms the single phase nature of the prepared material. The temperature dependence of the DC electrical resistivity shows a peak, corresponding to metal-insulator transition at T_{MI} ~ 264 K. Under an applied low magnetic field, the resistivity decreases from zero field resistivity and we have calculated the magnetoresistance and anisotropic magnetoresistance of our polycrystalline $La_{0.67}Ca_{0.33}MnO_3$ with respect to temperature. We found high values of magnetoresistance and anisotropic magnetoresistance at low temperatures, revealing the major role played by polycrystalline grains and grain boundaries in determining magnetoresistance of our polycrystalline $La_{0.67}Ca_{0.33}MnO_3$. The angular dependence of resistance follows $Sin^2\vartheta$ behaviour, indicative of uniaxial anisotropy of our polycrystalline $La_{0.67}Ca_{0.33}MnO_3$. This is shown in the figure. Incidentally, we have found evidence of spin correlations in the paramagnetic state above the metal-insulator transition temperature in our polycrystalline $La_{0.67}Ca_{0.33}MnO_3$. Notably, we

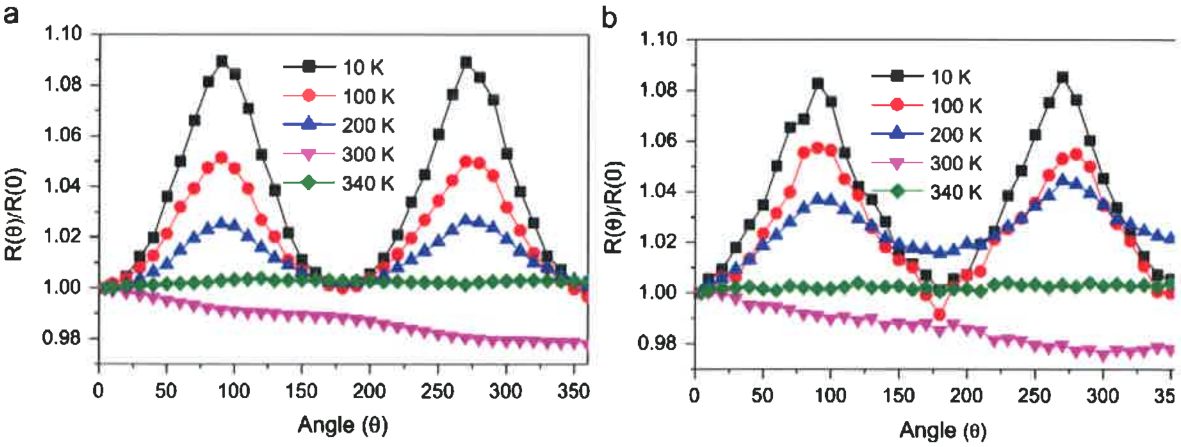


Figure : Normalized resistance, $R(\theta)/R(0)$ as a function of angle, θ of polycrystalline $La_{0.67}Ca_{0.33}MnO_3$ at different temperatures for (a) $I = 1$ mA and (b) $I = 0$ μA.

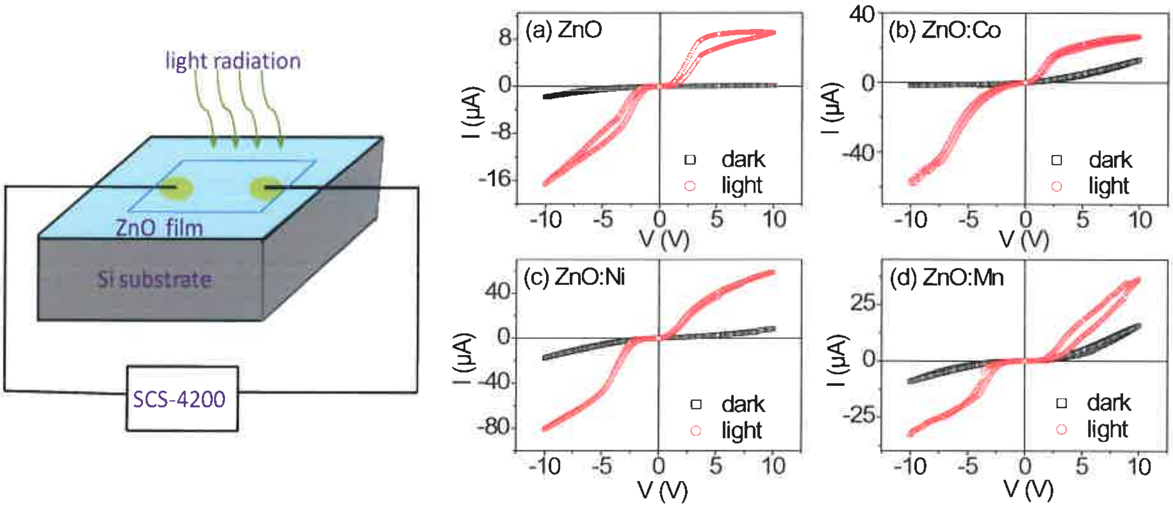
have observed deviations in $Sin^2\vartheta$ angular dependence of resistance for low current, which could help to ascertain the limiting current for operation of AMR devices of this polycrystalline $La_{0.67}Ca_{0.33}MnO_3$.

The FESEM measurement in this work was carried out in collaboration with Prof. G. U. Kulkarni, DST Unit on Nanoscience, Jawaharlal Nehru Centre for Advanced Scientific Research. This work has been published: Nagaiah Kambhala and S. Angappane, *Physica B: Condensed Matter,* **411**, 72 (2013).

Investigators: S. Angappane and Nagaiah Kambhala

6.22 *SYNTHESIS, CHARACTERIZATION AND PHOTORESPONSE STUDY OF UNDOPED AND TRANSITION METAL (CO, NI, MN) DOPED ZNO THIN FILMS*

The synthesis, characterization and photoresponse studies of undoped and transition metal doped zinc oxide thin films are carried out in this work, in prospect of visible light photo detection and sensor applications. The undoped and transition metal ions such as, Co, Ni and Mn doped ZnO films in this study were synthesized by chemical solution deposition, involving spin-coating. We have characterized the deposited films using x-ray diffraction, scanning electron microscopy, photoluminescence and UV-visible spectroscopy studies. The devices of the films for photoresponse study were fabricated by top Ag contacts on the film surface in metal-semiconductor-metal configuration. A schematic of the fabricated device is shown in figure. The current-voltage (*I-V*) characteristics and switching measurements of these devices were studied under the illumination of an incandescent lamp (see figure). Remarkably, the photoresponse study reveals higher photocurrent density of TM doped ZnO films compared to undoped ZnO. Particularly, Ni doped ZnO show a high ON/OFF ratio of 8 and highest photocurrent density of 0.7 mA/cm^2. Moreover, a less response time of ~ 200 ms were observed for our Ni doped ZnO films. Nevertheless, these films would be a potential candidate for visible-IR photodetector and light sensor applications.



Schematic diagram of the fabricated planar Ag/ZnO/Ag or Ag/ZnO:TM/Ag devices. I-V characteristics of (a) ZnO (b) ZnO:Co (c) ZnO:Ni (d) ZnO:Mn thin films with and without light illumination

The FESEM measurement in this work was carried out in collaboration with Prof. G. U. Kulkarni, DST Unit on Nanoscience, Jawaharlal Nehru Centre for Advanced Scientific Research. X-ray photoelectron measurements (XPS) measurement was done with help of Prof. S. M. Shivaprasad, Jawaharlal Nehru Centre for Advanced Scientific Research.

This work has been published: R. Rajalakshmi and S. Angappane, *Materials Science and Engg. B*, **178**, 1068 (2013).

Investigators: S. Angappane and R. Rajalakshmi

6.23 DESIGNING AC SUSCEPTIBILITY SAMPLE HOLDER FOR CLOSED CYCLE REFRIGERATOR (CCR)

We are fabricating a AC susceptibility sample holder for our existing CCR. The sample holder containing a coaxial mutual inductance coil system and temperature sensor will be cooled down to low temperatures using CCR. The induced voltage measured using a lock-in amplifier will be calibrated into ac susceptibility. The final wiring of the sample holder is being carried out.

Investigator: S. Angappane

6.24 HYBRID FILMS OF REDUCED GRAPHENE OXIDE WITH NOBLE METAL NANOPARTICLES AT A LIQUID/LIQUID INTERFACE

We have devised a simple and elegant method to obtain ultra-thin films of reduced graphene oxide (rGO) based hybrids with noble metal nanoparticles in a constrained environment at the interface of two immiscible liquids. The method involves in-situ reduction of metal-organic complexes (metal- triphenylphospine complex in toluene phase) and graphene oxide (aqueous phase) by tetrakis (hydroxymethyl) phosphonium chloride (THPC in aqueous phase) followed by self-assembly. The reduction may be performed in a single step where all the reactants are reduced in one step or in a sequential fashion wherein the rGO film is obtained initially followed by the reduction of metal-organics. Films of rGO with Au, Ag and Pd nanoparticles have been obtained that extends to cm scale and can be lifted on to various desirable substrates. The hybrid materials are characterized by UV-visible, infra-red and Raman spectroscopies, X-ray diffraction, scanning electron (SEM), transmission electron (TEM) and atomic force microscopies (AFM). UV-visible spectra confirm the presence of isolated metal nanoparticles grafted on to rGO layers and IR spectra revealed that triphenylphosphine ligands hang on to the surface of nanoparticles thereby acting as a capping agent. Raman spectra showed some intriguing results including intensity enhancement and splitting of G and D bands of rGO (Fig.1). Enhancement of intensity of Raman bands of rGO, known as surface enhanced Raman scattering is observed for rGO-metal nanoparticle films obtained by sequential reduction while intensity suppression and splitting of rGO bands is seen in single step produced films. This indicates a possible charge transfer interaction between rGO and metal nanoparticles.

The morphology of the films is studied by SEM (Fig.2). Subtle differences are observed for the hybrid films produced by the two methods. It can be seen that the films produced by single step method constitute a uniform mixture of metal nanoparticles with rGO layers (Fig. 2a) while the films obtained by the two-step method have a very non-uniform coverage of metal nanoparticles over rGO (Fig. 2b)The average size of the metal nanoparticles is comparatively smaller for the two-step method. The presence of metal nanoparticles is confirmed from energy dispersive spectra (EDS).

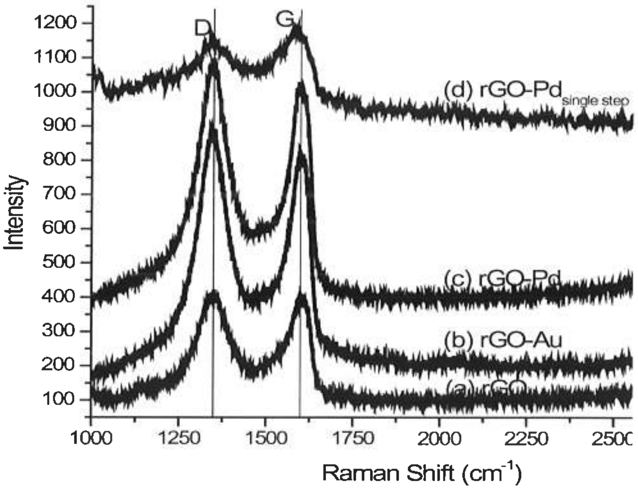


Figure 1: Raman spectra of rGO-metal nanoparticle films on Si/SiO$_2$ substrate (a) bare rGO (b) and (c) rGO-Au and rGO-Pd by sequential reduction (d) rGO-Pd by single step method.

A mechanism is proposed to explain the formation of the hybrid films at the liquid/liquid interface (Fig. 3). The reduction and transport of metal nanoparticles and graphene oxide across the water/toluene interface is facilitated by the increased thermal motion of the reactant molecules during heating. The simultaneous reduction of GO and metal precursor ensures a uniform mixture of rGO and metal nanoparticles in the case of single step method. The spontaneous assembly at the interface is driven by the capillary forces, which is quite appreciable for the planar rGO platelets. In the case of sequential deposition, THPC has to diffuse to the toluene phase through the cracks and defects in the rGO film for the reduction of metal nanoparticles and hence, the random anchoring of nanoparticles.

Investigators : Neena S. John, Bramhaiah Kommula

6.25 APPLICATION OF HYBRID FILMS AS CATALYTIC MEMBRANES

The application of rGO-metal nanoparticle films in catalysis is demonstrated using the model reaction of p-nitrophenol reduction to p-aminophenol by sodium borohydride. A major advantage of employing the hybrid films in catalysis is the easy immobilization of the films on substrates enabling a speedy recovery of the catalyst in addition to the stabilization provided by rGO matrix against aggregation of nanoparticles. The time evolution UV-Vis spectra of the reduction reaction in the presence of rGO-Pd nanoparticle films show a rapid decrease in the absorbance of nitrophenolate ions at 410 nm within half an hour (Fig. 4a). As the concentration of nitrophenol reduces, the concentration of the product aminophenol increases slowly whose absorption is observed at 310 nm. The kinetics of the uncatalyzed and

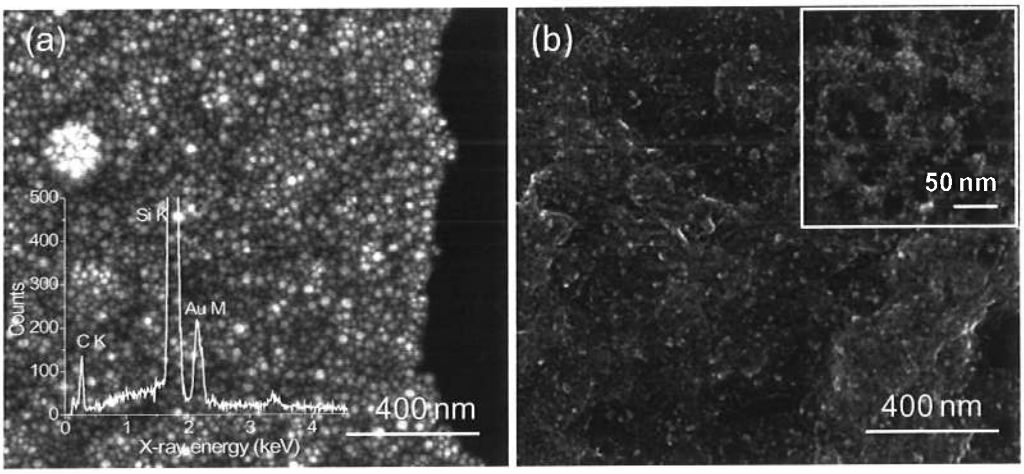


Figure 2: SEM images of the rGO-metal nanoparticle films formed at the liquid/liquid interface. (a) rGO-Au by single step method (b) rGO-Au by sequential reduction; top inset shows high magnification image and bottom inset gives EDS spectra.

catalyzed reactions is studied by plotting the absorbance of nitrophenolate ions against time (Fig. 4b). For the uncatalyzed reaction, hardly any change in the concentration of nitrophenol is seen with time while for all other cases a significant decrease in the concentration is noticed. The rate constants are calculated following pseudo-1st order kinetics.

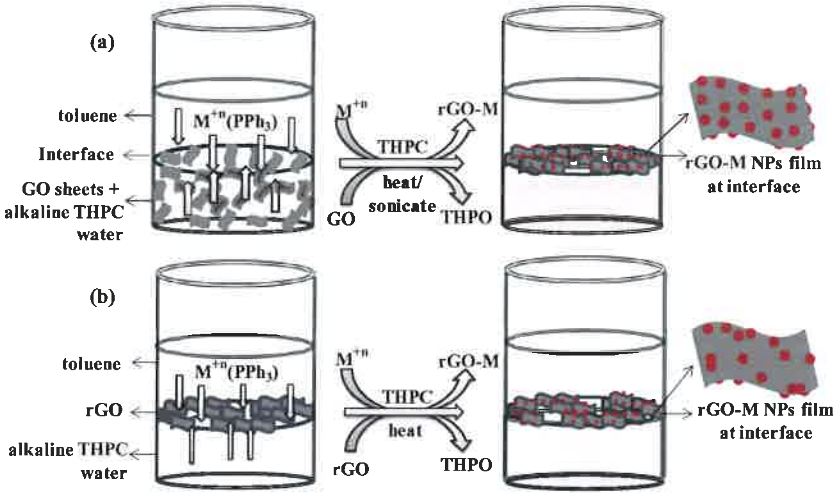


Figure 3: A schematic of the proposed mechanism for the formation of hybrid films at the water/toluene interface (a) single step method (b) sequential reduction.

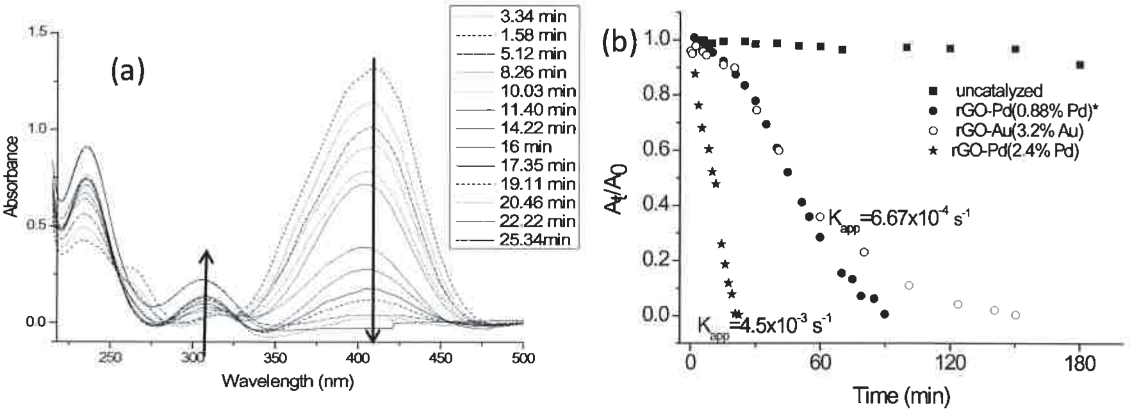


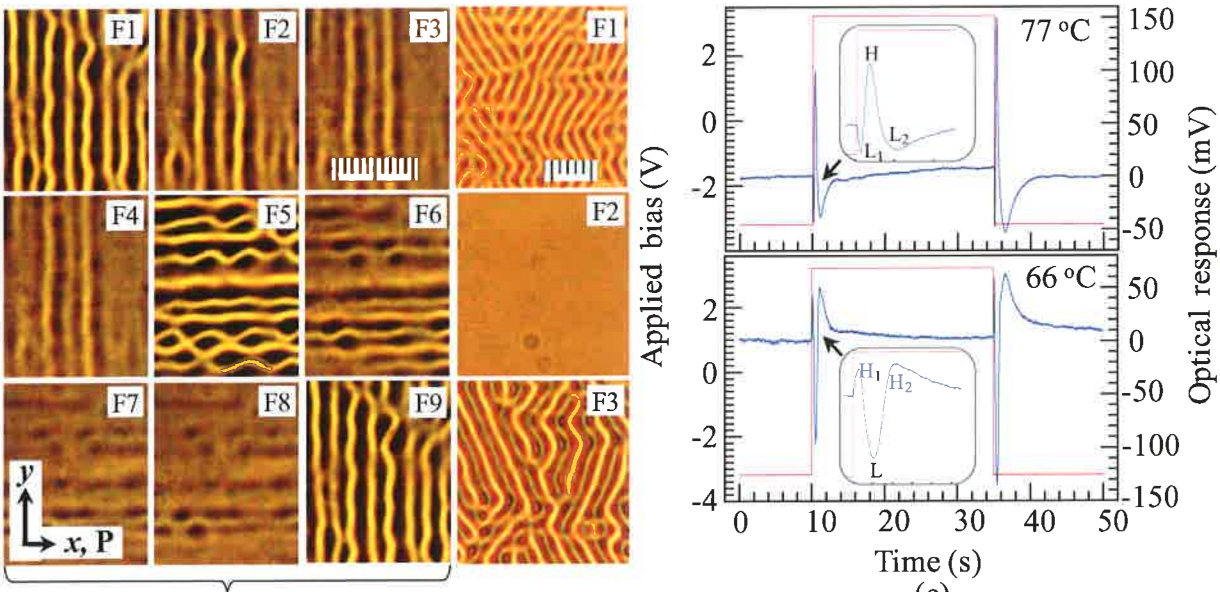
*Figure 4: (a) Time evolution of UV-Vis spectra during the reduction of p-nitrophenol with excess of sodium borohydride in the presence of rGO-Pd nanoparticle film supported on Si (b) Kinetics of the reduction catalyzed by rGO-metal nanoparticle hybrids supported on Si substrates with different metal loadings. The rate constants are calculated following pseudo 1st order kinetics. *The metal composition is given as atomic percentage calculated from EDS.*

This work has been published: K. Bramhaiah and Neena S.John, *RSC Advances*, **3**, 7765 (2013).

Investigators : Neena S. John and Bramhaiah Kommula

6.26 POLARITY-SENSITIVE TRANSIENT PATTERNED STATE IN A TWISTED NEMATIC LIQUID CRYSTAL DRIVEN BY VERY LOW FREQUENCY FIELDS

This work dwells on a low frequency electric instability exhibited by a rodlike nematic liquid crystal in the 90°-twisted configuration. Excitation by square wave electric fields of frequency less than 2 Hz is found to generate the Carr-Helfrich director modulation appearing transiently over a few seconds at each polarity reversal and vanishing almost completely under steady field conditions. Significantly, the instability is polarity sensitive, with the maximum distortion localized in the vicinity of the negative electrode, rather than in the midplane of the layer. This is revealed by the wave vector alternating in the two halves of the driving cycle between the alignment directions at the two substrates (Fig. 1).



(a) (b) (c)

Figure 1: (a) Transient evolution of vertical and horizontal stripe states occurring at polarity reversals of a square wave field in a 90°-twisted, nematic sample; 2 μm each scale division; frequency, f = 0.453 Hz; voltage, V = 5.1 V. Frames F1–F9 are from time lapse recordings, with a frame rate $f_R = 3.623\ s^{-1}$. Here $f = f_R/8$, so that frames recorded at successive polarity reversals (F1, F5, F9) are separated by three frames captured during field constancy (F2–F4 and F6–F8). (b) Transient evolution of zigzag stripes oriented predominantly along y and occurring at polarity reversals of a square wave field in an untwisted nematic layer uniformly aligned along x; f = 0.874 Hz, V = 5.1 V; 2 μm each scale division. Here $f = f_R/4$, so that the patterned state appears in alternate frames. (c) Electro-optic response in a twisted-nematic phenyl benzoate layer, driven by a 20 mHz, 3.2 V square wave field; each polarity reversal is followed by a transient sudden change in transmitted intensity. Parallel polarizers; mercury green light.

Besides the Carr-Helfrich mechanism, quadrupolar flexoelectric polarization arising under electric field gradient is strongly indicated as responsible for the development of the transient periodic order. Similar transient instability is also observed in other nematic compounds with varying combinations of dielectric and conductivity anisotropies, showing its general nature. The study also deals with various characteristics of the electro-optic effect that emerge from the temporal variation of optical response for different driving voltages, frequencies, and temperatures.

This work was carried out in collaboration with Pramoda Kumar, Department of Physics of Complex Systems, Weizmann Institute of Science, Rehovot 76100, Israel.

This work has been published: K. S. Krishnamurthy, Pramoda Kumar and M. Vijay Kumar, *Phys. Rev. E* **87,** 022504:1-11 (2013).

Investigators: K. S. Krishnamurthy and M. Vijay Kumar

7. SPONSORED PROJECTS

- A three year project entitled "Molecular design, synthesis and characterization of thermotropic liquid crystals with novel molecular architecture" under the DST Women Scientist Scheme A (WOS-A) was sanctioned in January 2011. The first instalment of grant has been received. The project is under progress. [Investigator: Uma S. Hiremath and Project Mentor: Geetha G. Nair].

- A three year SERB project proposal "Charge transport and calorimetric studies on liquid crystals and plastic crystals doped with metal nanoparticles" in collaboration with Dr. B.L.V. Prasad, NCL, Pune, was sanctioned in 2012. The first instalment of grant has been received. The project is under progress. [Investigator: S.Krishna Prasad]

- A three year SERB Fast Track project titled "Magnetic studies on magnetic ion doped ZnO thin films and resistive switching applications", was sanctioned in 2012. The first instalment of grant has been received. The project is under progress. [Investigator: S. Angappane]

- A three year fast-track project proposal entitled "Local conductance, gas sensing and molecular magnetism studies of electroactive systems based on Metal –Phthalocyanines" was sanctioned in 2012. The first instalment of grant has been received. The project is under progress. [Investigator: Neena Susan John].

- A three year SERB project proposal "Electro-optic and rheological investigations on liquid crystal gels" has been sanctioned in 2013. The project is under progress. [Investigator: Geetha G. Nair and C.V.Yelamaggad]

- A three year SERB project titled "Synthesis and characterization of novel thermotropic liquid crystals: Functional discotics, dimmers and dimer-like mesogens" has been sanctioned in 2013. The first instalment of grant has been received. The project is under progress. [Investigators: C.V.Yelamaggad and S. Krishna Prasad]

- An Indo-Bulgarian research project proposal entitled "Investigation of photostimulation effects in nano-structured liquid crystals" was sanctioned by DST in February 2013. The first instalment of grant has been received. The project is under progress. [Investigators:

Indian side - S.Krishna Prasad, Geetha G.Nair, D.S. Shankar Rao and C. V. Yelamaggad; Bulgarian side – Y. G. Marinov, A. G. Petrov, G. B. Hadjichristov, L. Todorova and M. Dencheva-Zarkova]

- As a part of the project “Dynamics of soft condensed matter” within the frame work of the scientific exchange programme between the Hungarian Academy of Sciences (HAS) and the Indian National Science Academy (INSA) Prof. K.A. Suresh visited Institute for Solid State Physics and Optics (ISSPO), Wigner Research Centre, Budapest for 3 weeks from August 28, 2013. He gave several lectures and interacted with the Scientists

  Under the ongoing INSA-Hungarian Exchange Programme, Mr. Balazs Szabo, Hungarian Scientist, Research Institute for Solid State Physics and Optics, Hungarian Academy of Sciences, Budapest, Hungary visited the Centre during 27 November to 8 December 2012 and gave a seminar entitled “Shear localisation in inhomogeneous granular materials” on 4 December 2012.

8. WOMEN’S DAY

The International Women’s Day was celebrated on 8 March 2012. On this occasion, the women staff members of the Centre visited Seva Sadan, an orphanage for girls situated in Malleswaram, Bangalore. The women staff members of the Centre donated four wall mounting fans to the Seva Sadan. They participated in a meeting with the staff and children.

Women members of the Centre at the Seva Sadan, an orphanage for girls.

Women members celebrating the 'Women's Day' with Seva Sadan children during lunch.

9. NATIONAL SCIENCE DAY

The Centre celebrated the National Science Day on 28 February 2013, declaring it the Open Day for the public. The occasion was celebrated by organizing a series of lectures by the CSMR scientists for an invited audience consisting of about 53 students and a few teachers of the Navkis Educational Centre, Mathikere, Bangalore. The talks were on :

Title	**Speaker**
Shining examples of Indian science	Prof. K. A. Suresh
Bioinspiration and innovation	Dr. P.Viswanath
The power of ten	Prof. H. L. Bhat
Zero waste situation: Is it utopian?	Dr. S.Krishna Prasad
Rubber bands and balloons	Prof. G. S. Ranganath

The students held a question and answer session after the lectures. After lunch, the students visited the laboratories and interacted with the researchers. Some special demonstrations were conducted to explain the research activities of CSMR.

Students of the Navkis Educational Centre at CSMR on the National Science Day.

Prof. H. L. Bhat delivering a talk on 'The power of ten' on the occasion of the National Science Day.

Prof. G. S. Ranganath explaining the mystery of rubber bands and balloons.

Dr. S. Krishna Prasad talking about waste management on 'Zero waste situation: Is it Utopian?'.

Prof. K. A. Suresh talking on 'Shining examples of Indian Science'.

Ms. N. G. Nagaveni explaining the synthesis of some achiral bent-core azo materials.

Ms. H. N. Gayathri discussing with the students about the nanoscale imaging of molecules using atomic force microscope.

Mr. Nagaiah Kambhala sharing the joy of research on ac susceptibility of materials at low temperature using squid magnetometer.

Ms. S. Vimala demonstrating rheological properties of gelation in a liquid crystal system.

10. PROF. S. CHANDRASEKHAR MEMORIAL LECTURE

The 9th Prof. S. Chandrasekhar Memorial Lecture was delivered by Prof. P. Balaram, Director, Indian Institute of Science, Bangalore on 6 August 2012. The lecture was on “Foldamers: Mimicking folded protein segments with unnatural polypeptide backbones” Prof. R. Narasimha, Chairman, Governing Council presided over the function.

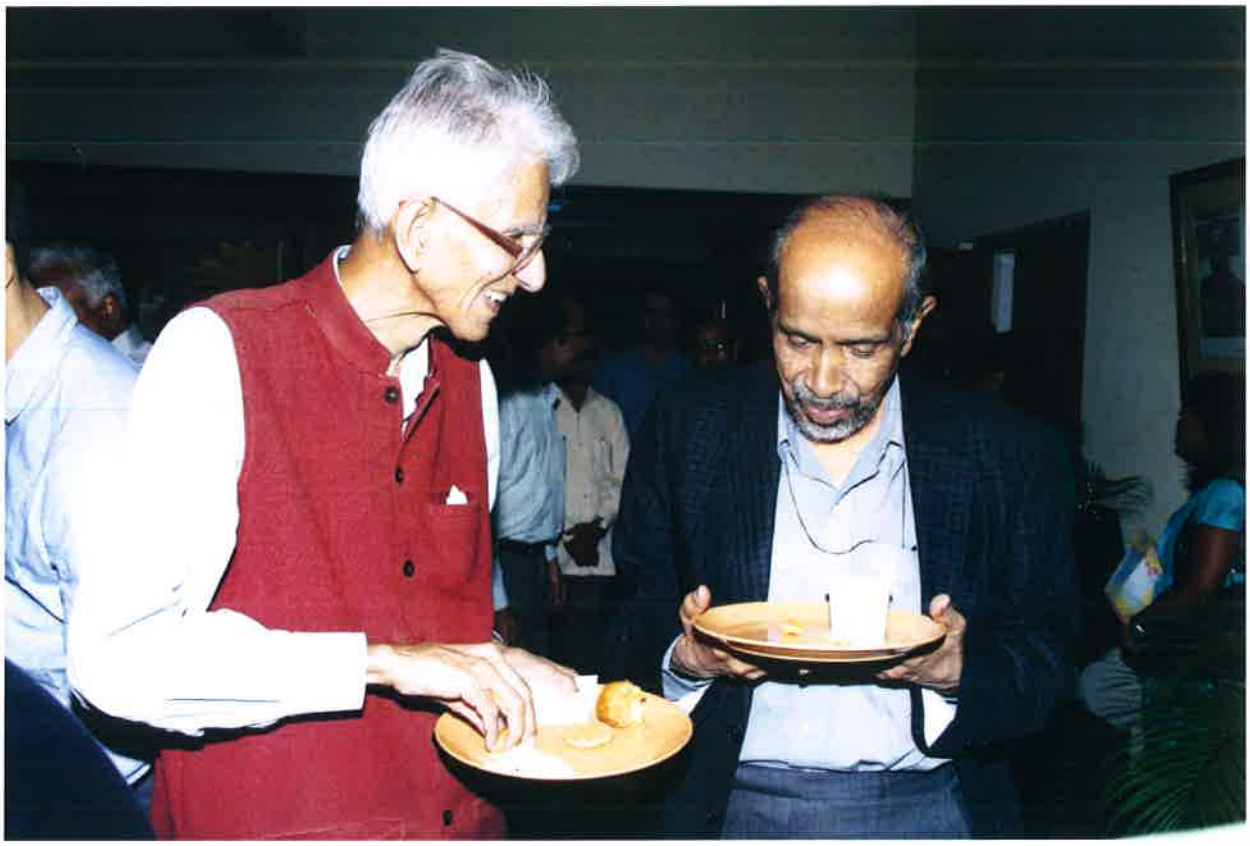
Prof. K. A. Suresh introducing the speaker Prof. P. Balaram on the occasion of the Prof. S.Chandrasekhar Memorial Lecutre.

Felicitation to Prof. P. Balaram, Director, Indian Institute of Science.

Prof. P. Balaram delivering a talk on "Foldamers: Mimicking folded protein segments with unnatural polypeptide backbones".

Prof. P. Balaram elaborating the statements 'Chemistry is the engine that drives biology' and 'Biology is the fuel that powers chemistry' during his talk.

Prof. Obaid Siddiqi and others enjoying the talk by Prof. P. Balaram on the occasion of the Chandrasekhar Memorial Lecture.



Prof. Obaid Siddiqi and Prof. R. Narasimha discussing some aspects of Molecular Biology, Aerospace Engineering and Soft Matter. Professor Siddiqi, the ever smiling, a regular visitor to CSMR, passed away on 26 July 2013 at Bangalore. The faculty and students of CSMR will miss him greatly.

Prof. N. Kumar talking with Mrs. Asiya Siddiqi and Dr.(Mrs.) Indira Chandrasekhar Brunner about the advances in Biological Sciences.

11. STUDENTS' PROGRAMME

- Ms. S. Sridevi was awarded the Ph.D. degree of the University of Mangalore, Mangalore for her thesis entitled "Experimental investigations on polar liquid crystals" in January 2013.
- Ms. R. Bhargavi attended the 24th International Liquid Crystal Conference, ILCC 2012 held at Mainz, Germany during 19-24 August 2012 and gave an oral presentation entitled "Enhanced Frank elasticity and storage modulus in a diamagnetic liquid crystalline". She also attended ICR 2012 – XVIth International Congress on Rheology held at Lisbon during August 5-10, 2012 and presented an oral presentation entitled "Liquid crystal gels exhibiting soft glassy rheological and enhanced electro-optic properties".

- Mr. Pramod Tadapatri attended the 24th International Conference on Liquid Crystals at Mainz, Germany during 19-24 August 2012 and made an oral presentation entitled "Dynamics of nematic loop disclinations: Theoretical and experimental results for inverse twist loop".
- Mr. M. Vijay Kumar attended the International symposium on macro- and supramolecular architectures and materials held during 21-25 November 2012 at Coimbatore and made an oral presentation "Composites of single walled carbon nanotubes and liquid crystals as switchable conductors".
- Ms. T. Shilpa Harish attended 19th National Conference on Liquid Crystals held at School of Physics and Materials Science, Thapar University, Patiala during November 21-23, 2012 and made a poster presentation entitled "Studies on Langmuir-Blodgett films of metallo-phthalocyanine".
- Ms. H. N. Gayathri attended 19th National Conference on Liquid Crystals held at School of Physics and Materials Science, Thapar University, Patiala during November 21-23, 2012 and made a poster presentation entitled "Studies on Langmuir-Blodgett multilayer films of alternatively deposited stearic acid and its mixture with octyl-cyanobiphenyl".
- Ms. Pappu Lakshmi Madhuri attended 19th National Conference on Liquid Crystals held at School of Physics and Materials Science, Thapar University, Patiala during November 21-23, 2012 and made a poster presentation entitled "Effect of polymer networks on the antiferroelectric smectic C_A* – smectic A phase transition".
- Ms. S. Vimala attended 19th National Conference on Liquid Crystals held at School of Physics and Materials Science, Thapar University, Patiala during November 21-23, 2012 and made a poster presentation entitled "Dielectric and spontaneous polarization studies in a ferroelectric liquid crystal gel".

- Dr. Sanjay K.Varshney attended 19th National Conference on Liquid Crystals held at School of Physics and Materials Science, Thapar University, Patiala during November 21-23, 2012 and made a poster presentation entitled "Functionalized triphenylene discotic liquid crystals: Towards a chiral core".
- Mr. Nagaiah Kambhala attended the Conference on Condensed Matter and Biological Systems (CCMB 13), held at Banaras Hindu University, Varanasi during 11-14 January 2013 and made a poster presentation entitled "Limiting current for anisotropic magnetoresistance of polycrystalline $La_{0.67}Ca_{0.33}MnO_3$".
- Ms. R.Rajalakshmi attended the 57th DAE Solid State Physics Symposium (DAE-SSPS 2012) held at IIT Bombay during 3-7 December 2012 and made a poster presentation entitled "Photoresponse study on transition metal (Co, Ni, Mn) doped ZnO thin films".
- Mr. K.Bramhaiah attended the Conference 'ACCMS-Theme meeting on 2D Nanostructures: Graphene and beyond' held at Indian Institute of Science, Bangalore during 29-30 July 2012 and made a poster presentation entitled "Facile synthesis of reduced graphene oxide decorated with metal nanoparticles and use as catalysts".
- Seventeen research students of the Centre visited the Kodaikanal Observatory of Indian the Institute of Astrophysics on 15 December 2012 and interacted with the Scientists of the Observatory.
- During the year, five new students joined CSMR for the Ph.D. Programme.
- About 25 students from Karnataka Rajya Vijnana Parishat visited the Centre on 13 March 2013. They interacted with the faculty and visited the labs.

12. AWARDS / HONORS

- Prof. K. A. Suresh was invited to be a Member of the International Scientific Committee of the 24th International Liquid Crystal Conference held during 19-24 August 2012 at Mainz, Germany.
- Dr. S. Krishna Prasad was invited to be a member of the International Advisory Committee for the International Conference on Nanotechnology 2012 held in Kuantan, Pahang, Malaysia, during 30 May – 1 June 2012.

13. POPULARIZATION OF SCIENCE

DR. S. KRISHNA PRASAD

	Name of the Institute	Date	Title of talk
1.	Karnataka Rajya Vijnana Parishat, Bantwala	25-11-2012	Why we need Nano?
2.	Karnataka Rajya Vijnana Parishat, Hubli	22-01-2013	An insight into Nano World.
3.	Karnataka Rajya Vijnana Parishat, Gadag	04-02-2013	Nanotechnology
4.	Karnataka Science & Technology Academy, Bagalkot	15-12-2012	The World of Liquid Crystals

DR. C.V.YELAMAGGAD

1.	Gudleppa Hallikeri College, Haveri	28-02-2013	"Liquid Crystals : Fundamentals, chemical aspects and applications"
2.	Department of Physics, Karnatak University, Dharwad.	23-02-2013	"Liquid crystals- An Unique State of Matter"

PROF. K. A. SURESH

1.	Indian Academy Pre-University College, Kalyan Nagar, Bangalore	11-10-2012	Inauguration of the Science Exhibition and talk on "Innovation and Science"

PROF. K. S. KRISHNAMURTHY

	Name of the Institute	Date	Title of talk
1.	Shimoga Zone* * Organized by Karnataka Rajya Vijnana Parishat in various Zones under "Karnataka Vijnana Vidya Jagruthi : Student - Scientist interaction programme"	18-12-2012	Liquid Crystals

PROF. G. S. RANGANATH

1.	Jawaharlal Planetorium, Bangalore	29-04-2012 & 30-04-2012	Interesting experiments in physics – 2 lectures
2.	Jawaharlal Planetorium, Bangalore	01-05-2012; 08-05-2012; 15-05-2012 & 22-05-2012	Course on thermal physics – 4 lectures

PROF. H. L. BHAT

1.	Kendriya Vidyalaya, I.I.Sc, Bangalore 560012	27-05-2012	Laser: Light of the 20th century
2.	M. E. S. College, Vidyaranyapura, Bangalore	07-08-2012	Electromagnetic Waves
3	M. E. S. College, Vidyaranyapura, Bangalore	30-08-2012	Lasers: past, present and future.
4.	INSPIRE Internship programme, National Degree college, Basavanagudi Bangalore=560004	28-10-2012	Crystals: Nature's Wonder
5.	Visvesvaraya Industrial and Technological Museum, Bangalore-560001	7-11-2012	C V Raman and Laser

	Name of the Institute	Date	Title of talk
6.	SVS PU College Bantwal (KRVP Programme)	24-11-2012	Laser: Light of the Twentieth Century
7.	Talent Development Centre, Indian Institute of Science, Kudhapura, Challakere Chitradurga District , Karnataka	15-16 July, 2012 30-31 July, 2012 10-11 Sept, 2012 24-25 Sept, 2012 09-10 Oct,2012 29-30 Oct, 2012 18-19 Nov,2012 23-24 Dec, 2012 22-23 Jan, 2013 07-08 Feb, 2013	Lectures with the following titles were given on these days: Electromagnetic Radiation, Photoelectric effect, Laser :Light of the 20th Century, Lasers and Applications, Laser as a teaching aid, Optics through Laser, Nuclear Energy, Thermal Physics, Atoms Nuclei and Molecules , Atomic Structure and related Developments

14. VISITS ABROAD AND TALKS GIVEN

- Prof. K. A. Suresh attended the 24th International Liquid Crystal Conference (ILCC) held at Mainz, Germany during August 19-24, 2012 and delivered an Invited Talk entitled "Spreading and retraction dynamics of a dye doped smectic domain at the air-water interface" during the conference. He also Chaired a Session during the conference.
- Prof. K.A. Suresh visited Institute for Solid State Physics and Optics (ISSPO), Wigner Research Centre, Budapest for 3 weeks from August 28, 2013 as a part of the INSA-HAS project "Dynamics of soft condensed matter". He also gave two colloquia on (i) "Electrical conductivity of Langmuir-Blodgett films of some novel discotic mesogenic molecules" on 11.09.2012 at Institute for Solid State Physics and Optics and "Studies on the spreading and retraction dynamics of a dye doped smectic domain at the air-water interface" on 12.09.2012 at Dept. of Complex Fluids, Wigner Research Centre for Physics.
- Prof. K.A. Suresh visited the Dept. of Biological Physics, Roland Eotvos University, Budapest and gave a talk on "Spatiotemporal patterns due to driven molecular precision at air-water interface" on 06.09.2012.

- Prof. K.A.Suresh visited the Biological Research Centre of the Hungarian Academy of Sciences, Szegad, Hungary on 13.09.2012 and gave a colloquium on "Patterns due to collective precission of mesogenic molecules at air-water interface: possible synthetic molecular motors".
- Prof. K.A.Suresh was invited to visit the Max Planck Institute for Dynamics and Self-Organization, Gottingen, Germany during 25-27 August 2012. He gave a colloquium at the Institute on 27.08.2012 on "Electrical conductivity in thin films of discotic liquid crystals".
- Dr. S.Krishna Prasad attended the International Conference on Nanotechnology 2012 held in Kuantan, Pahang, Malaysia, from May 30 – 1 June 2012 and gave a Keynote Lecture entitled "Liquid crystal-nanoparticle hybrids: realization of restricted geometries and enhanced electrical properties", and also Chaired a Session during the conference.
- Dr. P. Viswanath attended the first Asian Conference on Liquid Crystals held at Fuji Calm, Fuji-Yoshida, Japan during December 16-18, 2012 and gave an Invited Talk entitled "Dynamics of spreading of a dye doped smectic liquid crystal domain at air-water interface". He also visited the International Centre for Materials Nanoarchitechtonics at National Institute of Material Science, Tsukuba, Japan during December 19-23, 2012 and gave a seminar on "Spreading dynamics of a dye doped smectic liquid crystal domain at air-water interface" on December 21, 2012.
- Dr. Neena Susan John attended the International Conference for Young Researchers on Advanced Materials held at Singapore from July 1-6, 2012 and gave an oral presentation titled "Facile synthesis of free standing metal nanoparticle-reduced graphene oxide composites at air-water interface".
- Ms. R. Bhargavi, SRF, attended the 24th International Liquid Crystal Conference, ILCC 2012, held during August 19–24, 2012 at Mainz, Germany and gave an oral presentation titled

"Enhanced Frank elasticity and storage modulus in a diamagnetic liquid crystalline system".

- Ms. R. Bhargavi attended ICR 2012 – XVIth International Congress on Rheology held at Lisbon during August 5-10, 2012 and gave an oral presentation titled "Liquid crystal gels exhibiting soft glassy rheological and enhanced electro-optic properties".
- Mr. Pramod Tadapatri attended the 24th International Liquid Crystal Conference, ILCC 2012, held during August 19–24, 2012 at Mainz, Germany and gave an oral presentation titled "Dynamics of nematic loop disclinations: Theoretical and experimental results for inverse twist loops".

15. SEMINARS / TALKS GIVEN AT OTHER INSTITUTES

- Prof. K. A. Suresh attended the Conference on Condensed Matter and Biological Systems (CCMB13) held at BHU, Varanasi during 11-14 January 2013 and delivered a Plenary Talk titled "Collective precision of mesogenic molecules at air-water interface: Possible synthetic molecular motors". He also Chaired a Session during the conference.
- Dr. S. Krishna Prasad attended the Conference on Condensed Matter and Biological Systems (CCMB13) held at BHU, Varanasi during 11-14 January 2013 and gave an Invited Talk titled "Effect of a network of functionalized nanosilica particles on phase transitions in a long-chain alkane".
- Prof. K. A. Suresh attended the 19th National Conference on Liquid Crystals held at School of Physics and Materials Science, Thapar University, Patiala, Punjab during November 21-23, 2012 and gave an Invited Talk titled "Shearing of layers in a dye doped smectic domain at the air-water interface".
- Prof. K.S. Krishnamurthy attended the 19th National Conference on Liquid Crystals held at School of Physics and Materials Science, Thapar University, Patiala, Punjab during

November 21-23, 2012 and gave an Invited Talk titled "Flexoelectrically generated fanlike morphology in a bent-core nematic liquid crystal".

- Dr. C.V.Yelamaggad attended the 19th National Conference on Liquid Crystals held at School of Physics and Materials Science, Thapar University, Patiala, Punjab during November 21-23, 2012 and gave an oral presentation titled "Self-Assembly of tris(N-salicylideneaniline)s (TSANs) into fluid columnar structures: Synthesis and characterization".

- Dr. P. Viswanath attended the 19th National Conference on Liquid Crystals held at School of Physics and Materials Science, Thapar University, Patiala, Punjab during November 21-23, 2012 and gave an oral presentation titled "Multi-valent ion interactions with a mesogenic molecule at the air-water interface".

- Dr. S. Krishna Prasad visited University of Hyderabad, Hyderabad during 17 July 2012 and gave a talk on "Liquid crystals in nanoenvironment: realization of restricted geometries and enhanced electrical properties".

- Dr. C.V.Yelamaggad visited Gurubhavan, Hiriyur, and presented an Invited Talk titled "Liquid crystals- An unique state of matter" on the occasion of celebrating National Science Day by high school science teachers of Hiriyur and Chitradurga on 1 March 2013.

- Dr. S. Angappane attended the Workshop on Advances in nanomaterials and thin films (WANT-2013) held at National Institute of Technology, Tiruchirappalli (NIT-T) during 8-9 March 2013 and gave an Invited Talk titled "Exchange bias effects in core/shell nanoparticles and Effect of buffer layer on multiferroic thin films".

- Prof. H. L. Bhat visited RNS Institute of Technology, Bangalore and gave Valedictory Address during the Faculty development Programme on "Display materials and their applications" held on 12-13 April 2012.

- Prof. H. L. Bhat attended a workshop on "Research Aspirants on Material Science" held at Reva Institute of Technology and Management, Bangalore on 13 October 2012 and gave a Plenary Lecture on "Nonlinear optical materials".

16. LECTURES BY VISITORS

- Prof. Shin'ichi Nakatsuji, University of Hyogo, Japan visited the Centre on 4 June 2012 and gave a colloquium titled "Functional radical compounds with liquid crystal and field-effect transistor properties".

- Prof. K. Kaneto, Kyunshu Institute of Technology, Kitakyushu, Japan visited the Centre on 12 November 2012 and gave a colloquium titled "Novel fabrication of anisotopic polymer films for organic electronics".

- Under the ongoing INSA-Hungarian Exchange Programme, Mr. Balazs Szabo, Researcher, Research Institute for Solid State Physics and Optics, Hungarian Academy of Sciences, Budapest, Hungary visited the Centre during 27 November to 8 December 2012 and gave a seminar entitled "Shear localisation in inhomogeneous granular materials" on 4 December 2012.

- Dr. B.R.Ratna, Naval Research Laboratory, Washington, USA visited the Centre on 4 March 2013 and gave a seminar titled "Directed nanoscale assembly at the bio-nano interface".

17. SEMINARS GIVEN AT THE CENTRE

- Ms. H.N.Gayathri gave a seminar on "Atomic force microscope and ellipsometry studies on Langmuir-Blodgett films of mesogenic amphiphilic molecules" on 18 April 2012.
- Mr. Bramhaiah gave a seminar on "Synthesis and properties of graphene-inorganic hybrid materials employing chemical route" on 10 July 2012.
- Mr. Nagaiah Kambhala gave a seminar on "Synthesis, electrical and magnetic properties of some multigerroic and colossal magnetoresistance materials" on 13 July 2012.
- Ms. P. Lakshmi Madhuri gave a seminar on "Photo-induced effects on liquid crystals in restricted geometries" on 26 July 2012.
- Ms. Vimala .S. gave a seminar on "Electrical and viscoelastic studies on liquid crystal gels and composites" on 27 August 2012.
- Mr. Pramod Tadapatri gave a seminar on "Electric field generated instabilities in thermotropic liquid crystals" on 15 November 2012.

18. LIST OF SCIENTISTS AND RESEARCHERS

	Name	Designation
1.	Prof. K. A. Suresh	Scientist of Eminence
2.	Dr. S. Krishna Prasad	Scientist F
3.	Dr. Geetha G. Nair	Scientist D
4.	Dr. D. S.Shankar Rao	Scientist D
5.	Dr. Veena Prasad	Scientist D
6.	Dr. C. V. Yelamaggad	Scientist D
7.	Dr. P. Viswanath	Scientist C
8.	Dr. S. Angappane	Scientist C

9.	Dr. Neena Susan John	Scientist C
10.	Prof. K. S. Krishnamurthy	Emeritus Scientist
11.	Prof. H. L. Bhat	Visiting Professor
12.	Prof. G. S. Ranganath	Visiting Professor
13.	Dr. Uma S. Hiremath	Research Associate
14.	Mr. Pramod Tadapatri	Senior Research Fellow
15.	Mr. Prasad N.Bapat	Senior Research Fellow
16.	Ms. Rashmi Prabhu	Senior Research Fellow
17.	Ms. N. G. Nagaveni	Senior Research Fellow
18.	Ms. R. Bhargavi	Senior Research Fellow
19.	Mr. K. R. Vinaya Kumar	Senior Research Fellow
20.	Ms. T. Shilpa Harish	Senior Research Fellow
21.	Mr. M. Vijaykumar	Senior Research Fellow
22.	Ms. R. Rajalakshmi	Senior Research Fellow
23.	Ms. Hashambi K.Dambal	Senior Research Fellow
24.	Mr. Nagaiah Kambhala	Senior Research Fellow
25.	Ms. H. N. Gayathri	Senior Research Fellow
26.	Ms. Pappu Lakshmi Madhuri	Junior Research Fellow
27.	Ms. S. Vimala	Junior Research Fellow
28.	Mr. K. Bramhaiah	Junior Research Fellow
29.	Ms. M. Monika	Junior Research Fellow
30.	Ms. P. Srividya	Junior Research Fellow
31.	Mr. B. N. Veerabhadraswamy	Junior Research Fellow
32.	Mr. Chandan Kumar	Junior Research Fellow
33.	Mr. Arup Sarkar	Junior Research Fellow

19. ADMINISTRATIVE STAFF

	Name	Designation
1.	Shri Subhod M. Gulvady	Administrative Officer
2.	Shri Vivek Dubey	Accounts Officer
3.	Shri K. R. Shankar	Consultant in Accounts
4.	Shri L. Chandra Sekhar	Maintenance Engineer
5.	Smt . P. Nethravathi	Office Superintendent
6.	Dr. Sanjay K. Varshney	Technical Assistant
7.	Smt. Sandhya D. Hombal	Technical Assistant
8.	Shri M. Jayaram	U.D.C.
9.	Shri Pradeep V. Hegde	Library Assistant
10.	Shri Govindappa	Consultant in Administration

20. PUBLICATIONS DURING 2012-2013

Publications in Refereed Journals

1. Inhomogeneous Freedericksz effect in a quarter turn twisted achiral smectic C liquid crystal, K. S. Krishnamurthy and Pramoda Kumar, *Europhys. Lett.,* **102**, 66001 (2013)

2. Polarity-sensitive transient patterned state in a twisted nematic liquid crystal driven by very low frequency fields, K. S. Krishnamurthy, Pramoda Kumar and M. Vijay Kumar, *Phys. Rev. E,* **87,** 022504:1-11 (2013)

3. Self-assembly of hekates-tris(N-salicylideneaniline)s into columnar structures: Synthesis and characterization, A. S. Achalkumar, U. S. Hiremath, D. S. Shankar Rao, S. Krishna Prasad and C V. Yelamaggad, *J. Org. Chem.,* **78**, 527 (2013)

4. Anchoring transition induced by gelation in a liquid crystal system, R. Bhargavi, Geetha G. Nair, and S. Krishna Prasad, *ChemPhysChem*, **14**, 331 (2013)

5. Self-assembled pentacenequinone derivative for trace detection of picric acid, V. Bhalla, A. Gupta, M. Kumar, D. S. Shankar Rao, and S. Krishna Prasad, *ACS Applied Materials & Interfaces*, **5**, 672 (2013).

6. Synthesis, characterization and photoresponse study of undoped and transition metal (Co, Ni, Mn) doped ZnO thin films, R. Rajalakshmi and S. Angappane, *Materials Science and Engg. B*, **178**, 1068 (2013).

7. Hybrid films of reduced graphene oxide with noble metal nanoparticles generated at a liquid/liquid interface for applications in catalysis, K. Bramhaiah, Neena S.John, *RSC Advances*, **3**, 7765 (2013).

8. Anisotropic magnetoresistance studies of polycrystalline $La_{0.67}Ca_{0.33}MnO_3$, Nagaiah Kambhala and S. Angappane, *Physica B: Condensed Matter*, **411**, 72 (2013).

9. Unsymmetrical tetracatenar liquid crystals containing 2-phenylbenzoxazole: Synthesis and characterization, K.C. Majumdar, T. Ghosh, D.S. Shankar Rao and S. Krishna Prasad, *Liquid Crystals*, **40**, 305 (2013)

10. Variation of lexan polycarbonate properties by electron beam, K. Hareesh, C. Ranganathaiah, P. Ramya, R. Bhargavi, Geetha G. Nair, Sangappa, Ganesh Sanjeev, *Journal of Applied Polymer Science*, **127**, 2010, (2013)

11. Studies on lithium L-ascorbate dihydrate: An interesting chiral nonlinear optical crystal Rao, K. Raghavendra, H.L. Bhat, Suja Elizabeth, *Matls. Chem. and Phys.*, **137**, 756 (2013).

12. Lithium D-isoascorbate monohydrate, a new nonlinear optical material , K. Raghavendra Rao, C. Aneesh, H.L. Bhat, Suja Elizabeth, *Cryst. growth & design*, **113**, 97 (2013)

13. Light emitting, star-shaped tris(N-salicylideneaniline) discotic liquid crystals bearing trans-stilbene fluorophores: synthesis and characterization, Achal Kumar and C. V. Yelamaggad, *Tetrahedron Lett.*, **53**, 7108 (2012).

14. Spreading and retraction dynamics of a dye doped smectic liquid crystal domain at the air–water interface, P. Viswanath, K. A. Suresh and Bharat Kumar, *Soft Matter*, **8**, 11180 (2012).

15. Reentrant nematic phenomenon in a new class of low molar mass, single component liquid crystals, Rashmi Prabhu and C. V. Yelamaggad, *J. Phy. Chem. B*, **116**, 9549 (2012).

16. Photostimulated and photosuppressed phase transitions in liquid crystals, Invited Highlights article, S. Krishna Prasad, *Angew. Chem. Int. Ed.* **51**, 10708 (2012).

17. Influence of quenched disorder created by nanosilica network on phase transitions in tetracosane, M. Vijay Kumar and S. Krishna Prasad, *RSC Advances*, **2**, 8531 (2012).

18. Effect of hydrostatic pressure on the Frank splay and bend elastic constants, Prasad N. Bapat, D.S. Shankar Rao, S. Krishna Prasad, Uma S. Hiremath, *Thermochimica Acta,* **537**, 65 (2012)

19. Achiral bent-core azo compounds: effect of different types of linkage groups and their direction of linking on liquid crystalline properties, N. G. Nagaveni, Arun Roy and Veena Prasad, *J. Mater. Chem.*, **22**, 8948, (2012).

20. Synthesis and thermal behavior of chiral dimers : Occurrence of highly frustrated and cholesteric liquid crystal phases, G. Shanker and C. V. Yelamaggad, *New J. Chem.,* **36,** 918 (2012).

21. Synthesis and characterization of supramolecular, optically active bisamides derived from amino acids, G. Shanker, D. S. Shankar Rao, S. Krishna Prasad and C. V. Yelamaggad. *Tetrahedron*, **68,** 6528 (2012).

22. Proton NMR relaxation study on the uniaxial-biaxial nematic phase transition in A131 liquid crystal, A. Aluculesei, F. Vaca Chavez, C. Cruz, P. J. Sebastiao, N. G. Nagaveni, Veena Prasad and R. Y. Dong, *J. Phys. Chem. B.*, **116**, 9556 (2012).

23. Facile synthesis of reduced graphene oxide films at the air–water interface and *in situ* loading of noble metal nanoparticles, K.Bramhaiah, Neena S John, *Adv. Nat. Sci.: Nanosci. Nanotechnol.,* **3,** 045002 (2012).

24. Oxadiazole-based unsymmetrical chiral liquid crystal dimers: synthesis and mesomorphic properties, K.C. Majumdar, P. K. Shyam, D.S. Shankar Rao and S. Krishna Prasad, *Liquid Crystals,* **39**, 1358 (2012)

25. Oxadiazole-based non-symmetric liquid crystalline trimers terminating with ferrocene and cholesterol units exhibiting TGBC* phase over a wide thermal range, K.C. Majumdar P.K. Shyam, D.S. Shankar Rao and S. Krishna Prasad, *Liquid Crystals,* **39**, 1117 (2012)

26. Influence of polar substituents on the mesomorphism of non-symmetrical achiral four-ring bent-core compounds: synthesis and characterization, R. K. Nath, D. D. Sarkar, D.S. Shankar Rao and N.V.S. Rao, *Liquid Crystals,* **39**, No. 7, 889 (2012).

27. Dielectric behaviour of a ferroelectric liquid crystal dimer, S. K. Gupta, D. Pratap Singh, R. Manohara, Uma S. Hiremath and C. V. Yelmaggad, *Liquid Crystals,* **39,** 1125 (2012).

28. Bend flexoelectricity of a polymorphic mesogen, S. Sridevi, Uma S. Hiremath, C.V. Yelamaggad, A.G. Petrov, S. Krishna Prasad, *Bulg. J. Phys*, **39**, 3 (2012)

29. Interplay between polarity and chirality in the electric-field-responsive columnar phase of a dipeptide derivative, N. Koizumi, G. Shanker, F. Araoka, Ken Ishikawa, C. V. Yelamaggad and H. Takezoe, *NPG Asia Materials*, **4,** doi:10.1038/am.2012.20 2012 (2012).

In press

1. Effect of pressure on the dielectric behavior of a bent-core liquid crystal, Prasad N. Bapat, D. S. Shankar Rao, S. Krishna Prasad, U. S. Hiremath, and C. V. Yelamaggad, *Phys. Rev., E,* (in press).

2. Structural characterization and molecular order of rod-like mesogens with three and four ring core by XRD and 13C NMR spectroscopy, M. K. Reddy, S.K. Kalluru, K.Yoga, M. Prakash , T. Narasimhaswamy , A. B. Mandal , N. P. Lobo , K. V. Ramanathan , D. S. Shankar Rao and S. Krishna Prasad, *J. Phys. Chem. B* (in press)

3. Observation of chiral smectic C phase over wide thermal range with novel phase sequences in rigid, bulky chiral dimers, Uma S. Hiremath, Halley M. Menezes, Geetha G. Nair, D. S. Shankar Rao and S. Krishna Prasad, *J. Mater. Chem.* (in press)

4. Dual frequency conductivity switching in a carbon nanotube/ liquid crystal composite, S. Krishna Prasad, M. Vijay Kumar and C.V. Yelamaggad, *Carbon* (in Press)

5. Confinement driven effects in a room temperature ferroelectric liquid crystal: X-ray, linear and non-linear dielectric investigations, M. Vijay Kumar, S. Krishna Prasad, D.S. Shankar Rao and E.P. Pozhidaev, *Phase Transitions* (in press).
6. Photoluminescent columnar zinc(II) bimetallomesogen of tridentate [ONO]-donor Schiff base ligand, C. R. Bhattacharjee, C. Datta, Gobinda Das, D. Das, P. Mondal, S. Krishna Prasad and D.S. Shankar Rao, *Liquid Crystals* (in press).

7. Composites of single walled carbon nanotubes and liquid crystals as switchable conductors, S.Krishna Prasad, *Nanosystems: physics, chemistry, mathematics* (in Press)

8. Proton and alpha particle induced changes in thermal and mechanical properties of Lexan polycarbonate, K. Hareesh, Pintu Sen, Ravishankar Bhat, R. Bhargavi, Geetha G. Nair, Sangappa, Ganesh Sanjeev, *Vaccum* (in press)

9. Anomalous dielectric behavior in the nematic and isotropic phases of a strongly polar–weakly polar binary system, M. Sarvamangala, M. Vijay Kumar, S.M. Khened, S. Basavaraja, D.S. Shankar Rao and S. Krishna Prasad, *Phase Transitions* (in press).

10. Azo substituted V-shaped liquid crystalline compounds: synthesis and mesophase characterisation, N. G. Nagaveni and Veena Prasad, *Phase transitions*, (in press).

Publications in Conference Proceedings

1. Photoresponse study on transition metal (Co, Ni, Mn) doped ZnO thin films, R. Rajalakshmi, S. Angappane, *AIP Conference Proceedings*, **1512**, 1050 (2013).

CENTRE FOR SOFT MATTER RESEARCH
BENGALURU

STATEMENT OF ACCOUNTS
FOR THE YEAR 2012 – 2013
AND
THE BALANCE SHEET AS ON 31.03.2013

G.R. VENKATANARAYANA
CHARTERED ACCOUNTANTS
Partners :
CA. G.R. Venkatanarayana, B.Com., F.C.A.,
CA. G.S. Umesh, B.Com., F.C.A.,

No. 618, 75th Cross, 6th Block
Rajajingar, Bangalore-560 010.
Ph: 23404921 / 64537325
Fax: 23500525
Email: grvauditor@gmail.com
grvenkat@sify.com

AUDITOR'S REPORT TO THE MEMBERS OF THE GOVERNING BODY OF CENTRE FOR SOFT MATTER RESEARCH, BANGALORE

We have audited the attached Balance Sheet of **Centre for Soft Matter Research** as at March 31, 2013, the Income & Expenditure Account for the year ended on that date and the Receipts and Payment account for the year ended on that date annexed thereto. These financial statements are the responsibility of the management of Centre for Soft Matter Research. Our responsibility is to express an opinion on these financial statements based on our audit.

We conducted our audit in accordance with auditing, standards generally accepted in India. Those standards require that 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 a test basis, evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by Management as well as evaluating the overall financial statements presentation. We believe that our audit provides reasonable basis for our opinion.

We report that:

1. We have obtained all the information and explanations, which to the best of our knowledge and belief were necessary for the purpose of our audit.

2. In our opinion proper books of accounts as required by law have been kept by the Centre for Soft Matter Research so for as it appears from our examination of those books.

3. The Balance Sheet , Income and Expenditure Account and Receipts and Payment account dealt with by this report are in agreement with the books of account.

4.The Balance Sheet and Income and Expenditure Account dealt with by this report are prepared in accordance with the Accounting Standards issued by the Institute of Chartered Accountants of India subject to the following observations:

(i) Non-Provisions of accrued liability in respect of leave encashment which is not in conformity with the Accounting, Standard 15 [Accounting for retirement benefits

.........2

Chartered Accountants

in the financial statements of Employers] issued by the Institute of Chartered Accountants of India.

(ii) The amount spent on acquisition of fixed assets has been deducted from the total grants/ subsidies received in the Income & Expenditure account. This is not in conformity with the Accounting Standard- 5 issued by the Institute Of Chartered Accountants of India. It has been explained that this format has been consistently used to present the accounts before the authority who grant the funds.

5. In our opinion and to the best of our information and according to the explanations given to us and subject to notes on accounts and our qualifications in para 4 above, the said accounts give a true and fair view in conformity with the accounting principles generally accepted in India:

(a) in the case of Balance Sheet, of the state of affairs of the Centre for Soft Matter Research as at March 31, 2013; and

(b) in the case of Income and Expenditure Account, of the excess of Income over Expenditure for the year ended on that date.

For M/s G R Venkatanarayana
Chartered Accountants

(G R Venkatanarayana)
Partner
Membership No. 018067
Firm Regn. No. 004616S

Place : Bangalore
Date: 23.09.2013

M/s. G.R. VENKATANARAYANA
Chartered Accountants
618, 75th Cross, 6th Block
Rajajinagar, BANGALORE-560 010

CENTRE FOR SOFT MATTER RESEARCH
JALAHALLI, BANGALORE - 560 013

BALANCE SHEET AS AT 31ST MARCH, 2013

(Amount in Rupees)

I. CORPUS / CAPITAL FUND AND LIABILITIES	SCH	As at 31.03.2013	As at 31.03.2012
CORPUS / CAPITAL FUND	1	14,88,94,731	12,66,98,360
RESERVES AND SURPLUS	2	-	-
EARMARKED PROJECTS FUNDS	3	89,68,596	43,26,483
SECURED LOANS AND BORROWINGS	4		-
UNSECURED LOANS AND BORROWINGS	5	-	-
DEFERRED CREDIT LIABILITIES	6	-	-
CURRENT LIABILITIES AND PROVISIONS	7	20,63,311	16,80,098
TOTAL		**15,99,26,638**	13,27,04,941

II APPLICATION OF FUNDS/ASSETS			
FIXED ASSETS	8	8,73,00,214	8,97,89,703
INVESTMENTS - FROM EARMARKED/ENDOWMENT FUNDS	9	-	-
INVESTMENTS - OTHERS	10	-	-
CURRENT ASSETS, LOANS, ADVANCES ETC.,	11	7,26,26,424	4,29,15,238
TOTAL		**15,99,26,638**	13,27,04,941
NOTES ON ACCOUNTS	24		

As per our report of even date,
for M/s. G.R.VENKATANARAYANA,
Chartered Accountants,

Praveer Asthana
(PRAVEER ASTHANA)
DIRECTOR

Vivek Dubey
(VIVEK DUBEY)
ACCOUNTS OFFICER

(G.R.VENKATANARAYANA)
PARTNER
M. No. 018067

PLACE :BANGALORE
DATE 23-09-2013

M/s. G.R. VENKATANARAYANA
Chartered Accountants
613, 75th Cross, 5th Block
Rajajinagar, BANGALORE-560 010

CENTRE FOR SOFT MATTER RESEARCH
JALAHALLI, BANGALORE - 560 013

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31ST MARCH, 2013

(Amount in Rupees)

A - INCOME	**SCH**	**2012-13**	**2011-12**
Income from Sales / Services	12	-	-
Grants / Subsidies:	13	6,00,00,000	5,76,74,000
Fees / Subscriptions	14	-	-
Income from Investments(income on investments from earmarked / endowment Funds)	15	-	-
Income from Royalty, Publications etc.,	16	-	-
Interest earned	17	59,00,479	23,13,063
Other Income	18	1,38,551	1,16,835
Increase / (decrease) in stock of finished goods and work-in-progress	19	-	-
TOTAL (A)		***6,60,39,030***	6,01,03,898

B - EXPENDITURE			
Establishment Expenses	20	1,85,87,623	1,67,76,262
Other Administrative Expenses etc.,	21	1,24,32,396	1,21,46,708
Expenditures on Grants, Subsidies etc.,	22	78,82,451	2,18,83,043
Interest	23	-	-
TOTAL (B)		***3,89,02,470***	5,08,06,013
C.BALANCE BEING SURPLUS / ~~DEFICIT~~ (A-B)		2,71,36,560	92,97,885
D. Add:- Prior Period Income		5,50,114	-
E. Less: Prior Period Adjustment		3,501	-
F. SURPLUS / ~~DEFICIT~~ CARRIED TO CORPUS / CAPITAL FUND (C+D-E)		**2,76,83,173**	**92,97,885**
NOTES ON ACCOUNTS	24		

As per our report of even date,
for M/s. G.R.VENKATANARAYANA,
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PLACE :BANGALORE
DATE 23-09-2013

M/s. G.R. VENKATANARAYANA
Chartered Accountants
618, 75th Cross, 6th Block
Rajajinagar, BANGALORE-560 010

CENTRE FOR SOFT MATTER RESEARCH
JALAHALLI, BANGALORE - 560 013

RECEIPTS AND PAYMENTS FOR THE PERIOD / YEAR ENDED 31ST MARCH, 2013

(Amount in Rupees)

RECEIPTS		As at 31.03.2013	As at 31.03.2012
I Opening Balances			
1) Cash in Hand		Nil	Nil
2) Bank Balances		29,63,648	
a) Indian Bank	1,216		29,817
b) State Bank of India	9,65,186		6,18,201
c) State Bank of Mysore 1	19,89,748		17,086
d) State Bank of Mysore 2	5498		64868
e) Bank of India	1,000		1000
f) Union Bank of India	1,000		
II Grants-in-aid from DST, Govt of India		6,00,00,000	5,76,74,000
III Interest Earned		64,50,593	
a) On Savings Bank Accounts	2,39,948		1,18,679
b) On Fixed/Term Deposits	62,10,645		21,94,384
IV Other Income		51,687	
a) Stale cheque	13,136		
b) License Fee	17,734		9,336
c) Recovery of Electricity & Water Charges	-		4,685
d) Miscellaneous Receipts	20,817		2,610
e) Overheads recovery on project (WOS-A-1 Project (USH))	-		1,00,000
V Other Recoveries etc.,		6,69,082	
A) Earnest Money Deposit & Security Deposit	6,69,082		2,50,609
B)		31,32,019	
i) C. P. F. Employees Contribution	4,22,675		3,77,616
ii) Income Tax Deducted at source from staff, contractor & rent and Professional Tax	1270983		7,08,893
iii) Advance to suppliers/others etc.,	2,21,362		4,60,011
iv) Staff Advance Recovery	7,53,222		42,150
v) CPF Advance Recovery	83300		-
vi) New Pension Scheme Tier -1	3,80,477		3,02,613
C)		1,11,450	
i) Establishment Receipts	57,629		12,93,867
ii) Other Administrative Receipts	53,821		
iii) Refund of TDS			4
VI Investments			
a) Fixed/Term deposits matured		7,67,34,595	7,62,64,239
b) Sale of Fixed Asset		8000	Nil
VII Grants/Financial Assistances received for Earmarked Projects		61,75,000	
a) Indo Bulgarian Project -CF	2,75,000		Nil
b) SERC (NSJ) Project- CF	11,50,000		Nil
c) SERB Project (SA) -CF	14,00,000		Nil
d) SERB(SKP) Project -CF	33,50,000		Nil
TOTAL		**15,62,96,074**	**14,05,34,868**

PAYMENTS		As at 31.03.2013	As at 31.03.2012
I. Establishment Expenses		1,69,24,180	1,65,43,631
II Administrative Expenses		1,22,68,600	1,20,29,366
III Fixed Assets (Additions)		78,82,451	2,18,83,043
IV A) Remittances/Refunds etc.,			
a) Earnest Money Deposit & Security Deposit		4,64,706	2,24,307
b) CPF Advance and other		83,301	-
B) Remittances/Refunds etc.,		52,85,594	
a) C.P.F. Employees Contribution	4,22,675		3,77,616
b) C.P.F. CSMR Contribution	261504		2,32,631
c) Income Tax Deducted at source from staff, contractor & rent and Professional Tax	12,72,294		7,08,893
c) Duties & Taxes	71,977		94,870
d) Advance to suppliers/others etc.,	8,23,648		5,26,733
f) Staff Advances	7,36,680		1,98,000
g) New Pension Scheme Tier 1	3,80,477		3,02,613
V h) Telephone Deposit	-		500
i) Provisions for last year paid	13,16,339		
Investments			
VI Fixed/Term Deposits made		10,31,02,506	8,37,19,423
VII Earmarked Project Expenses		44,38,200	7,27,594
Closing Balance			
1) Cash in Hand		Nil	Nil
2) Bank Balances		58,46,336	
a) Indian Bank	5,63,293		1,216
b) State Bank of India	36,30,953		9,65,186
c) State Bank of Mysore 1	16,44,506		19,89,748
d) State Bank of Mysore 2	4,945		5,498
e) Bank of India	1,584		1,000
f) Union Bank of India	1,055		1,000
TOTAL		**15,62,96,074**	**14,05,34,868**

As per our report of even date,
for M/s. G.R.VENKATANARAYANA,
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(PRAVEER ASTHANA)
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ACCOUNTS OFFICER

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M. No. 018067

PLACE :BANGALORE
DATE 23-09-2013

M/s. G.R. VENKATANARAYANA
Chartered Accountants
618, 75th Cross, 6th Block
Rajajinagar, BANGALORE-560 010

CENTRE FOR SOFT MATTER RESEARCH
JALAHALLI, BANGALORE - 560 013

SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31ST MARCH, 2013

(Amount in Rupees)

		As at 31.03.2013	As at 31.03.2012
SCHEDULE 1 - CORPUS / CAPITAL FUND:			
As Per Previous Balance Sheet		**126698360**	110460166
ADD: Fixed Assets purchased during the year		**7882451**	21883043
		134580811	132343209
ADD: Excess of Income over Expenditure for the year		**27683173**	9297885
LESS: Depreciation for the year		**13369253**	14942734
	TOTAL	**148894731**	126698360
SCHEDULE 2 - RESERVES AND SURPLUS:	**TOTAL**	-	-
SCHEDULE 3 - EARMARKED / PROJECT FUNDS: (See Annexure A for details)	**TOTAL**	8968596	4326483
SCHEDULE 4 - SECURED LOANS AND BORROWINGS:	**TOTAL**	-	-
SCHEDULE 5 - UNSECURED LOANS AND BORROWING	**TOTAL**	-	-
SCHEDULE 6 - DEFERRED CREDIT LIABILITIES:	**TOTAL**	-	-
SCHEDULE 7-CURRENT LIABILITIES & PROVISIONS:			
A) CURRENT LIABILITES:			
1) Statutory Liabilities		-	-
2) Other Liabilities - Security Deposit		568135	363759
3) Stale Cheque		13136	-
	TOTAL (A)	**581271**	363759
B) **PROVISIONS:**			
Salaries & Allowances		1459568	12,93,867.00
Audit Fee		22472	22,472.00
	TOTAL (B)	**1482040**	1316339
	TOTAL (A+B)	**2063311**	1680098
SCHEDULE 8 - FIXED ASSETS	**TOTAL**	**87300214**	89789703
SCHEDULE 9- INVESTMENTS FROM EARMARKED / ENDOWMENT FUNDS:		-	-
SCHEDULE 10 - INVESTMENTS - OTHERS:		-	-
SCHEDULE 11 - CURRENT ASSETS,LOANS, ADVANCES:			
A) CURRENT ASSETS:			
1) Inventories		-	-
2) Sundry Debtors:		-	-
3) Cash Balances in Hand(including Cheques/Drafts and Imprest)		-	-
4) Bank Balances:- Nationalised Banks			
a. Term Deposit Receipts (includes margin money)		65626280	39258369
b. Current Account : SBM Vyalikaval		4945	5498
c. Savings Accounts:			
Bank of India (Malleswaram)		1584	1000
Union Bank of India (Malleswaram)		1055	1,000
Indian Bank (BEL Road)		563293	1216
SBI (Jalahalli)		3630953	965186
SBM (RMV Extn)		1644506	1989748
	TOTAL (A)	**71472616**	**42222017**

Vivek Dubey

B) LOANS,ADVANCES AND OTHER ASSETS:

1) Loans	-	-
2) Advances and Other amounts recoverable in Cash or in kind or for value to be received:	461023	268981
a) KPTCL Deposit (SERC/CLCR)	347740	347740
b) Telephone	76500	76500
3) Claims Receivable from SERB	268545	-
TOTAL (B)	**1153808**	**693221**
TOTAL (A+B)	**72626424**	**42915238**

SCHEDULE 12 - INCOME FROM SALES / SERVICES:

TOTAL	-	-

SCHEDULE 13 - GRANTS / SUBSIDIES:

(Irrevocable Grants & Subsidies Received)

Dept of Science & Techonolgy Government of India **TOTAL**	**60000000**	**57674000**

SCHEDULE 14 - FEES / SUBSCRIPTIONS:

TOTAL	-	-

SCHEDULE 15 - INCOME FROM INVESTMENTS:

TOTAL	-	-

SCHEDULE 16 - INCOME FROM ROYALTY, PUBLICATIONS ETC.:

TOTAL	-	-

SCHEDULE 17 - INTEREST EARNED:

1) On Term Deposits - Nationalised Banks	5660531	2194384
2) On Savings Accounts - Nationalised Bank	239948	118679
TOTAL	**5900479**	**2313063**

SCHEDULE 18 - OTHER INCOME:

Licence Fee/Hostel Room rent recovery	17734	9336
Miscellaneous Income	120817	102810
TDS - Income Tax	0	4
Electricity & Water Charges Recovery	0	4685
TOTAL	**138551**	**116835**

SCHEDULE 19 - INCREASE (DECREASE) IN STOCK OF FINISHED GOODS & WORK IN PROGRESS:

	-	-

SCHEDULE 20 - ESTABLISHMENT EXPENSES:

1) Salaries, Allowance and Wages to Staff	13164799	11617328
2) Medical Expenses Reimbursed	11911	29605
3) Salaries-Allowances,bonus & Awards	33650	29196
4) Fellowship & Book Grant	5377263	5100133
TOTAL	**18587623**	**16776262**

SCHEDULE 21 - OTHER ADMINISTRATIVE EXPENSES,ETC:

Audit Fee	22472	22472
Chemicals, Glasswares & Consumables etc.,	2857467	3811770
Duties & Taxes	71977	94870
Electricity & Water Charges	1804111	1603138
Fees & Professional charges	212866	216360
Foreign Travel	298893	259236
Fuel Charges for Genset	43568	55908
Hospitality Charges	86062	74394
House Keeping Charges	1062180	936496
Journals & Periodicals	1497863	1074456
Lab Tools & Implements	1200	58371
Liveries	12566	15599
Local Conveyance	411150	382159

N.M.R. Recording & Sample analysis charges	196735	153592
Other Miscellaneous Charges / Bank Charges	79553	53383
Postage & Advertisement Charges	173636	79716
Printing & Stationery	267741	284015
Registration & Renewals	46700	19500
Rent & Insurance	371123	372779
Repairs & Maintenance	1085343	1025279
Security Charges	929072	822882
Seminar and Conferences	70622	40000
Telephone Charges	157681	156481
Travel Expenses	671815	533852
TOTAL	**12432396**	**12146708**
SCHEDULE 22 - EXPENDITURE ON GRANTS, SUBSIDIES ETC: (Fixed assets)	**7882451**	**21883043**
SCHEDULE 23 - INTEREST:	-	-

As per our report of even date,
for M/s. G.R.VENKATANARAYANA,
Chartered Accountants,

(PRAVEER ASTHANA)
DIRECTOR

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PLACE :BANGALORE
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CENTRE FOR SOFT MATTER RESEARCH
JALAHALLI, BANGALORE - 560 013

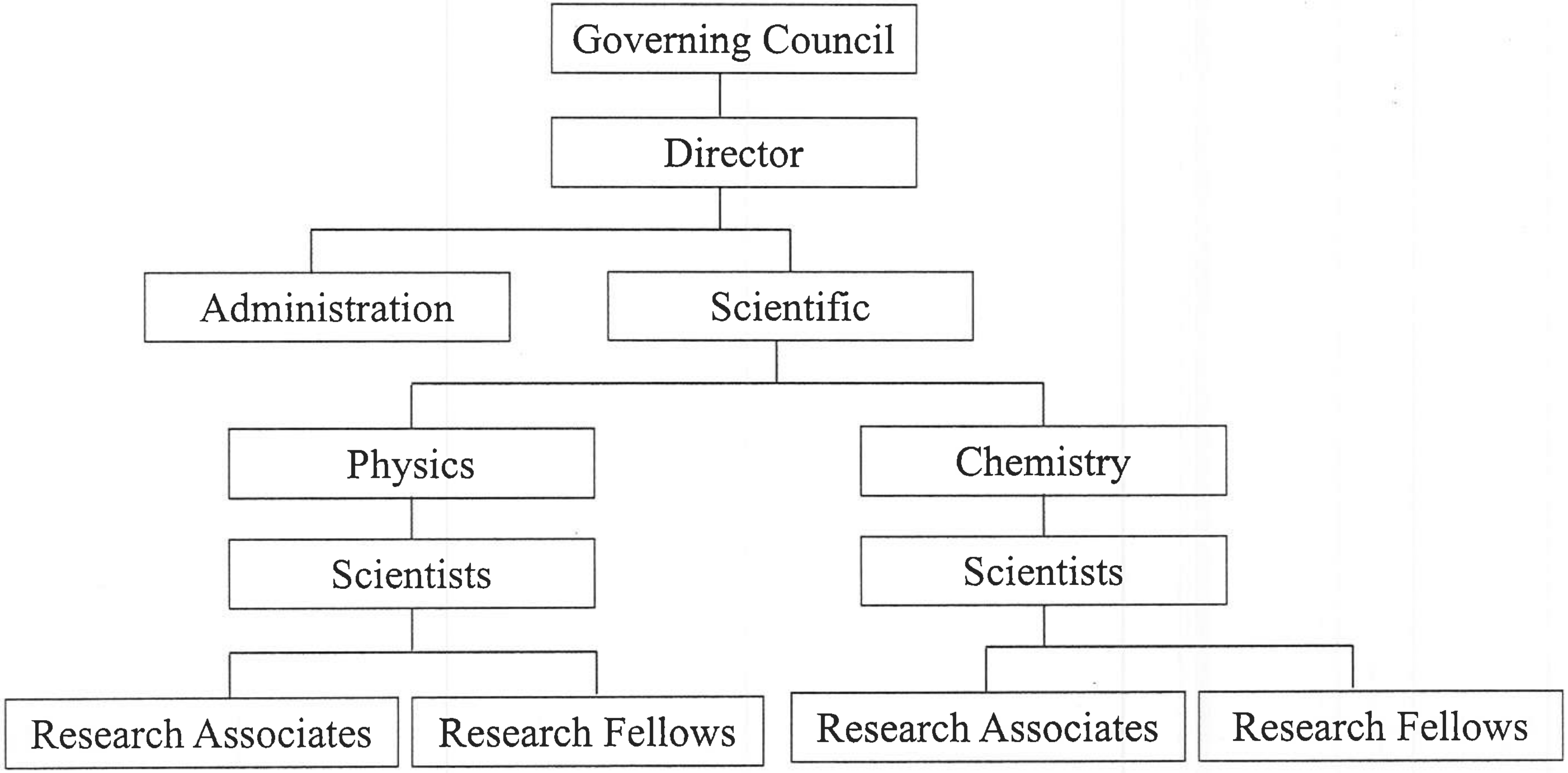
SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31ST MARCH, 2013

Annexure - A to Schedule 3

(Amount in Rupees)

SCHEDULE 3 - EARMARKED / PROJECTS FUNDS	PROJECT / WISE BREAKUP																		
	SERC	SERC (2004-05	SERC (CVY1)	INDO-US	INDO-US (SKP)	INDO - JAPAN	CSIR (NMITLI)	CSIR (SK)	CSIR (CVY)	CSIR 2162_CVY3	INDO-BULGARIA	SERC HL Bhat	WOS-A-1 (USH)	SERB (SKP)	SERB (SA)	SERB (NSJ)	INDO-Bulgerian (SKP)	CURRENT YEAR TOTAL	PREVIOUS YEAR
a) Opening Balance of the Funds	1672610	103547	822282	391008	126475	175319	766471	20122	12875	115034	15164	176462	-70886	0	0	0		4326483	5592909
b) Additions to the Funds:																			
i) Grants	-	-	-	-	-	-	-	-	-	-	-	-	-	3350000	1400000	1150000	275000	6175000	0
ii) Income from Investments made on Account of India	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-
TOTAL (a+b)	1672610	103547	822282	391008	126475	175319	766471	20122	12875	115034	15164	176462	-70886	3350000	1400000	1150000	275000	10501483	5592909
c) Utilisation/Expenditure towards objectives of Funds:																			
i) Capital Expenditure																			
Fixed Assets	-	-	-	-	-	-	-	-	-	-	-	-	-						
Others																			
ii) Revenue Expenditure																			
Salaries, Wages and Allowances etc.,	-	-	-	-	-	-	-	-	-	-	-	-	3,85,000	1,09,761	24,642	-		519403	498591
Consumables	-	-	-	-	-	-	-	-	-	-	-	-	-	11990	150000	-		161990	129003
Depreciation	152554	15532	123343	10378	18978	-	114972	3018	1974	17255	-	-	-	197921	180405	-		836330	538832
Overheads	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-		0	100000
Grant Refunded	0	0	0	0	0	0	0	0	0	0	15164	0	0	0	0	0	0	15164	0
TOTAL (c)	152554	15532	123343	10378	18978	0	114972	3018	1974	17255	15164	0	385000	319672	355047	0	0	1532887	1266426
NET BALANCE AT THE YEAR END (a+b-c)	1520056	88015	698939	380630	107497	175319	651499	17104	10901	97779	0	176462	-455886	3030328	1044953	1150000	275000	**8968596**	4326483

Centre for Soft Matter Research (CSMR)
Organisation Chart



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मृदु पदार्थ अनुसंधान केंद्र
डाक बॉक्स १३२९
प्रो। यू । आर । राव मार्ग
जालहल्ली
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