Centre for Soft Matter Research

(Formerly Centre for Liquid Crystal Research)

Bengaluru

मृदु पदार्थ अनुसंधान केंद्र

(पूर्व में तरल क्रिस्टल अनुसंधान केंद्र)

बेंगलूरु

Annual Report
2010 - 2011

वार्षिक रिपोर्ट

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CENTRE FOR SOFT MATTER RESEARCH

(Formerly Centre for Liquid Crystal Research)

BENGALURU

ANNUAL REPORT

2010 – 2011

THE GOVERNING COUNCIL (2010-2011)

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FOREWORD

The Centre for Soft Matter Research (CSMR) is under the administrative control of the Department of Science and Technology (DST), Ministry of Science and Technology, Government of India. It was earlier known as Centre for Liquid Crystal Research (CLCR). On 1 September 2010, CLCR was renamed as Centre for Soft Matter Research. This was done in view of the current international trends in research and on the recommendation of the Research Advisory Board to expand the scope of the Centre's research programmes. The new name was approved by the higher bodies and also the Department of Science and Technology, Government of India. The amendment was registered by the Registrar of Societies, Government of Karnataka on 28.04.2010.

The Annual Report for the year 2010-2011, contains highlights of the research, development and academic programmes of the Centre, and lists the scientific output of the Centre like the academic activities and publications for the period 1 April 2010 to 31 March 2011.

The research activities at the Centre have grown from the traditional area of thermotropic liquid crystals to other soft materials like gels, ferrogels, polymers, thin films, membranes, nanomaterials, nanoweeds and so on. The aim will be to strengthen research in these areas and to encompass other frontier areas of Soft Matter. CSMR being the only Centre in the country exclusively devoted to research and development in Soft Matter, will actively collaborate with other institutes in the country having research interests in 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 converted to an autonomous institution under the administrative control of the Department of Information Technology. In the year 2003, the Centre was brought under the administrative control of the Department of Science and Technology (DST), Ministry of Science and Technology. DST has been providing core support in the form of grant-in-aid for conducting basic and applied research in liquid crystals 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 Soft Matter research including research on liquid crystal materials. The Centre has been renamed as "Centre for Soft Matter Research" (CSMR) with effect from 1 September 2010.

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

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, in its proposal submitted to the Planning Commission provided for CLCR, an outlay of Rs.12.88 crores for the 10th plan period. The grants were received by CLCR from the Department of Information Technology up to the financial year 2002-03. In 2003, the Centre came under the administrative control of the Department of Science and Technology (DST), Ministry of Science & Technology. From 2004 onwards, grants have been received by CLCR from DST. The year-wise break-up of the outlay proposed and approved for the Centre as per the 11th Plan document, is given below.

Table: Proposed & approved Outlay as per the Eleventh Plan document (Rs. in Lakhs)

2007-08	2008-09	2009-10	2010-11	2011-12	Total
284.00 (FE 84.00)	415.00 (FE 179.00)	373.00 (FE 111.00)	442.00* (FE 151.00)	586.00 (FE 262.00)	2100.00 (FE 797.00)

* During the year 2010-11, a grant of Rs. 324.95 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.

Centre has 1 SC/ST employee working under Group C.

HINDI DAY

The Centre observed the Hindi Day on 14 September 2010. On this occasion, Smt. Chilukal Pushpalata, Lecturer, Seshadripuram College delivered a seminar titled "Sahitya evam prayog

moolak Hindi: Ek adhyayan" in Hindi. The lecture was followed by a lively discussion with the faculty and students.

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

4. RESEARCH ADVISORY BOARD

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

1.	Prof. N. Kumar Raman Research Institute	Chairman
2.	Prof. Chandan 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 Central Research Laboratory, Bharat Electronics Limited	Member
7.	Prof. K. A. Suresh Centre for Soft Matter Research	Convener

IN-HOUSE MEETING

An In-house and Research Advisory Board meeting was conducted on 4 May 2010 and the following talks were delivered by the faculty of the Centre .

Speaker	Title
K.A. Suresh	Electrical conductivity in the LB films of a mesogenic oligomer

S. Krishna Prasad	Diminution of the ordering in plastic and liquid crystalline phases by confinement
Geetha G. Nair	Soft glass rheology in liquid crystalline gels formed by a monodisperse dipeptide
D.S.Shankar Rao	High pressure dielectric investigations of aerosil-nematic liquid crystal composites
Veena Prasad	Photo-controlled electro-optical properties: A new dimension to the bent-core liquid crystals
C.V. Yelamaggad	Supramolecular liquid crystals: Manifestation of molecular chirality in macroscopic fluid structures
P. Viswanath	Spreading and retraction dynamics of dye doped liquid crystalline domains at the air-water interface
S. Angappane	Novel interface anisotropy and exchange bias effects in Fe_3O_4/γ-Fe_2O_3 core/shell nanoparticles
K. S. Krishnamurthy	Electro hydro dynamic states in a bent-core nematic liquid crystal

5. FINANCE COMMITTEE

The third meeting of the Finance Committee with the following members was held on 5 August 2010.

1.	Dr. Praveer Asthana, Acting Director, CSMR	Chairman
2.	Smt. L. Indumathy, Nominee of Financial Advisor, DST	Member
3.	Dr. T. G. Ramesh, National Aerospace Laboratories, Bengaluru	Member
4.	Prof. K. A. Suresh, Scientist of Eminence, CSMR	Invitee
5.	Shri S. Gulvady, Administrative Officer, CSMR	Invitee

6. RESEARCH AND DEVELOPMENT ACTIVITIES

6.1 ENHANCEMENT OF ANISOTROPIC CONDUCTIVITY, ELASTIC, AND DIELECTRIC CONSTANTS IN A LIQUID CRYSTAL-GOLD NANOROD SYSTEM

Owing to their unusual behavior in comparison with the bulk state, and more importantly with their spherical counterparts, gold nanorods (AuNR) provide tremendous opportunities as well as challenges particularly from the viewpoint of applications in sensors, imaging and bio-medical aspects. A dimension that has been developed in such systems is the research on composites of liquid crystals (LC) with gold nanoparticles. For example, in a system comprising spherical particles, we observed two orders of magnitude increase in the absolute value of the electrical conductivity. We have carried out electrical conductivity (σ), dielectric constant (ε) and elastic constant measurements on a nematic liquid crystal (LC) doped with small concentrations of gold nanorods. Using spectroscopic (two peaks in the surface plasmon resonance profile) and electron-microscopic techniques, the anisotropic shape of the gold particles was established (see Figure 1a). This LC-nanoparticle complex, shows not only orders of magnitude higher σ, but also stabilizes its anisotropy (Figure 1b). The ε data suggests increased ordering in the nematic phase and improved anti-parallel correlation of molecules in the isotropic phase. For the first time, a substantial enhancement in the ratio of the splay and the bend elastic constants is also observed.

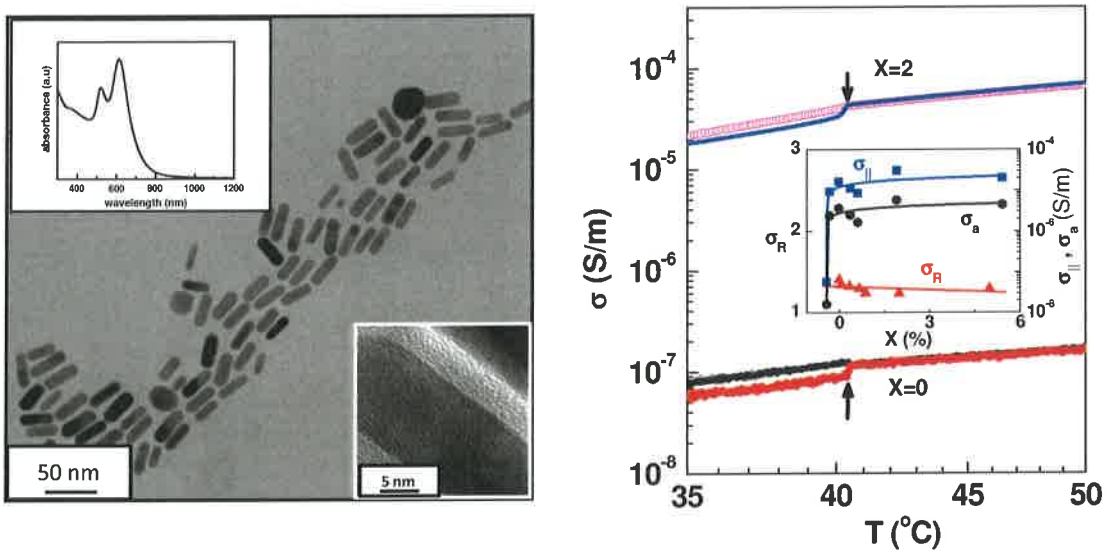


Figure 1: (a) Left panel: Electron microscopy image and the surface plasmon resonance profile of the gold nanoparticles. (b) Right panel: Temperature (T) dependence of the electrical conductivity for the pure LC (X=0) and the LC-AuNR complex (X=2) in the isotropic (T above the arrow marks) and nematic (T below the

arrows) phases. The twin values in the nematic indicate the anisotropy in the value. Inset shows the parallel contribution and the anisotropy of the conductivity as a function of the AuNR concentration.

Based on the observation that there is significant increase in conductivity upon the field-driven mechanical rotation of the molecules, we suggest a possible electro/magneto-mechanical conductivity switch. For the differential increase in the elastic constants, we argue that the aspect ratio of the nanoparticles vis-à-vis the LC molecules plays the main role. The aspect ratio of AuNR is about a factor of ~ 3-4, as compared to a value of ~ 5 for the individual LC molecules. Since the increase along the lateral dimension is more (which reduces the aspect ratio), it could be affecting the elasticity in the lateral direction more, resulting in an enhancement of K_3. In fact, in pure LC systems, such a feature is known: addition of bridging groups in the aromatic part of the molecule, which are out-of plane with respect to the longitudinal direction of the molecule, tend to increase the K_3/K_1 ratio.

This work has been published : S. Sridevi, S. Krishna Prasad, Geetha G. Nair, Virginia D'Britto and B.L.V. Prasad, Appl. Phys. Lett., 97, 151913 (2010).

Investigator : S.Krishna Prasad

6.2 CONFINEMENT-DRIVEN WEAKENING OF THE ROTATOR PHASE TRANSITIONS IN AN ALKANE THROUGH A POSSIBLE TRICRITICAL POINT

Normal alkanes are also the principle content in petroleum products such as fuels and lubricants. The behavior in nanoconfinement situations of alkanes is of great interest since the new physics resulting from finite-size effects, reduced dimensionality, surface forces etc. can help in a better understanding of the various thermophysical and interfacial phenomena, having implications in many industrial and geophysical operations, apart from contributing to the field of transitions among ordered phases. Between the true crystalline and isotropic (Iso) phases, certain normal alkanes, 1-alcohols and semifluorinated alkanes, exhibit a sequence of intermediate phases termed as rotator phases. The nomenclature suggests increased rotational degrees of freedom in comparison with the features for a true crystalline solid. These phases consist of layered structures with three-dimensional crystalline order of the molecular centres, but no long-range orientational order. It is this orientational melting, but an intact positional order that these phases are known for, and in this aspect they have some

similarities with the plastic phases such as the Crystal B (CrB) observed in liquid crystalline systems. The rotator phases are well known for their interesting surface crystallization, negative thermal compressibility, anomalous high heat capacity and high thermal expansion properties. Apart from the industrial uses such as in the petroleum and lubricating industry, they have important applications like thermohydraulic microactuators.

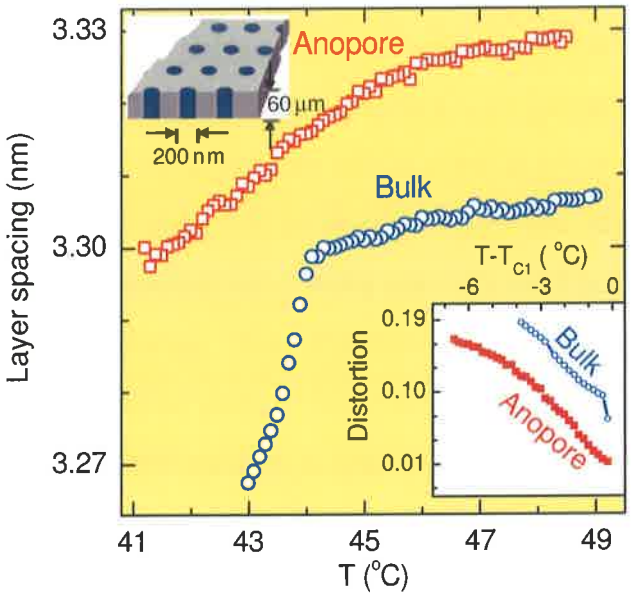


Figure 2: Thermal variation of the layer spacing in the bulk and confined situations. The abrupt lowering of the spacing for the bulk sample marks the onset of R1-R5 transition. In contrast, the Anopore sample shows a gradual decrease below the temperature marked with an arrow. The corresponding lattice distortion is shown in the inset.

Understanding behaviour of materials under confinement is important in many areas of science from both theoretical and experimental points of view. In this regard, special emphasis has been paid to study the influence of the size of the system on phase transitions, which have raised fundamental questions, challenging the known static and dynamic behaviours. The main differences between the bulk and the confined systems are caused by the competition between the typical correlation lengths driving the phase structure or dynamics, and the finite size of the system, leading to a cut-off or finite size effect, with the static or the dynamical correlation length limited to the size of the confining matrix. We have demonstrated that confinement on the mesoscopic length scale has dramatic effects on the transitions between rotator phases, by probing the ordering within, and normal to the layers. We observe unique weakening of the transitions, especially that between the R1 and R5 phases, the extent of which is dependent on the magnitude of the length scale. Together with the lattice distortion parameter we look at the order parameter behaviour (See Figure 2) and

show that confinement could be a strong possibility to realize the tricritical point on the R1-R5 boundary, a feature that is significant in view of the recent theoretical prediction of such a point, albeit in the pressure-temperature plane. These studies serve as complementary to the observations recently made by us (S. Krishna Prasad, S. Sridevi, D. S. Shankar Rao, J. Phys. Chem. B 114, 7474 (2010)) in the case of a plastic phase formed in a liquid crystalline material. While the finite size effects are operative in both the situations, the influence is much stronger in the present case, the reasons for which are being explored with further measurements involving plastic phases with different structural features. The present studies also throw light on the aptness of the description of phase transitions in alkanes employing Landau free energy expressions similar to the ones used for the liquid crystalline systems. Especially important from this view point is the experimental finding of how confinement can weaken the coupling between different order parameters, thus paving a new pathway to achieve a tricritical point. Theoretical studies wherein the finite length scale imposed externally (in the form of pore size) is incorporated into the free energy equations are expected to yield more interesting scenarios.

This work has been published : M. Vijay Kumar, S. Krishna Prasad and D.S. Shankar Rao, Langmuir, 26, 18362 (2010)

Investigator : S.Krishna Prasad

6.3 ANOMALOUSLY LARGE BEND ELASTIC CONSTANT AND FASTER ELECTRO-OPTIC RESPONSE IN ANISOTROPIC GELS FORMED BY A DIPEPTIDE

During 2010-11, we have carried out rheological, static and dynamic Freedericksz transformation measurements on an anisotropic thermoreversible gel (E7G) formed by gelation of a nematic liquid crystal (NLC) with a monodisperse dipeptide. The storage and loss modulii obtained from a low strain oscillatory shear experiment display that the material forms a weak anisotropic gel, and undergoes a sharp thermal transition to an anisotropic sol state. Freedericksz transformation studies employing an electric field for reorientation of the molecules present a surprising result: the gel possesses a very large Frank bend elastic constant value, which are orders of magnitude higher than that for the high temperature sol state as well as that for the neat NLC used. On the other hand, the splay elastic constant

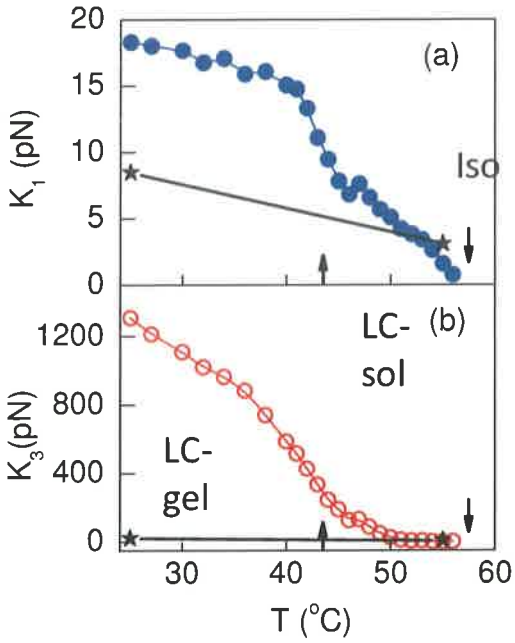


Figure 1: Temperature variation of (a) K1 and (b) K3 across LC-gel to LC-sol transition of E7G. Whereas K1 increases by a factor of 5 from LC-sol to LC-gel phase, K3 has a dramatic enhancement by more than two orders of magnitude. For comparison, K1 and K3 values obtained for the host LC, E7 are shown as asterisks in (a) and (b). The LC-gel to LC-sol and LC-sol to Isotropic (Tiso) phase transitions of E7G are indicated by upward and downward arrows respectively. The lines through data points are merely a guide to eye.

shows a relatively small increase. Further, these elastic constants show systematic, but non-linear variation, with the concentration of the gelator. Attractive features of the electro-optic switching when the sol transforms to the gel state are (i) the vanishing of the undesirable backflow effect, and (ii) nearly an order of magnitude decrease in the switching speed. In both the gel and sol states the extracted rotational viscosities are comparable to the values of the neat NLC at corresponding temperatures. In contrast, the bulk dynamic viscosity is more than

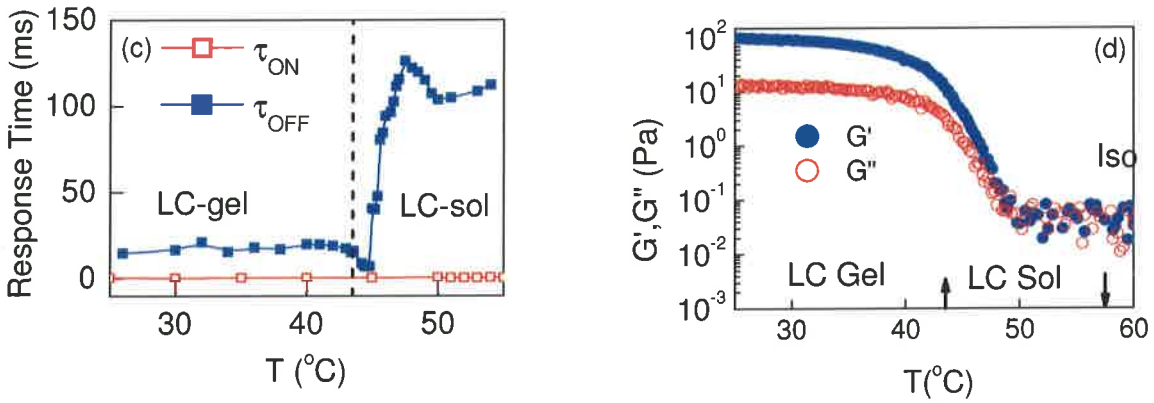


Figure 2: (c) Electro-optic (EO) response times for the on (τ_{ON}) as well as the off (τ_{OFF}) states when the voltage (1 kHz sine, 76 VRMS) is applied to the LC composite and subsequently removed. Fig. *(d) Thermal variation of G' and G" of the LC composite measured in the LVR. At low temperatures G' is higher than G" and at 43.5 °C both G' and G" decrease by 2-3 orders of magnitude indicating a transition to sol phase.*

three orders of magnitude higher in the gel. These studies also demonstrate that the anisotropic gel to anisotropic sol transition seen in this weak gel can be tracked by simply monitoring the static or dynamic Freedericksz transformation.

Investigator : Geetha G. Nair

6.4 ENHANCED FRANK ELASTICITY AND STORAGE MODULUS IN A DIAMAGNETIC LIQUID CRYSTALLINE FERROGEL

Combining the magnetic properties of metal particles and the orientational anisotropy of a liquid crystal has been of attraction owing to potential technological and bioengineering applications. The target is to achieve the ferromagnetic state while retaining the fluid environment of a nematic liquid crystal (NLC). Such a realization in a low molecular weight material which undergoes physical gelation is all the more advantageous since it can exploit the electrical switching and the concomitant birefringence change etc. in the sol state as well have the structure frozen in the gel state.

In an attempt to study such ferrogels, we have performed calorimetry, XRD, dielectric, elastic, rheological and magnetic measurements on composites by doping an NLC with FePt nanoparticles and an organogelator. While the XRD data suggests that the orientational correlations of NLC are slightly strengthened by the presence of the particles and the gelator, the Frank bend elastic constant increases by two orders of magnitude indicating the mechanical rigidity of the gels. The magnetic measurements reveal that the superparamagnetic feature of the FePt particles is weakened in these ferrogels. This is surprising since recently it has been shown that a polymer ferronematic retains the ferromagnetic characteristics of the doped metal particle. These results suggest that the local environment of the particles has an important role in quenching the thermal fluctuations which in turn influences their magnetic interaction. Despite the bulk viscosity of the gelated system being high due to the trapping of NLC by the gelator, the immediate neighbourhood of the particles is still a fluid with enough orientational and translational freedom. Outcome of this is an ineffective quenching of the thermal fluctuations and consequently weak magnetic interactions.

This work was carried out in collaboration with Nitesh Kumar and A. Sundaresan, Chemistry and Physics of Materials Unit, Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore.

Investigator : Geetha G. Nair

6.5 HIGH PRESSURE STUDIES

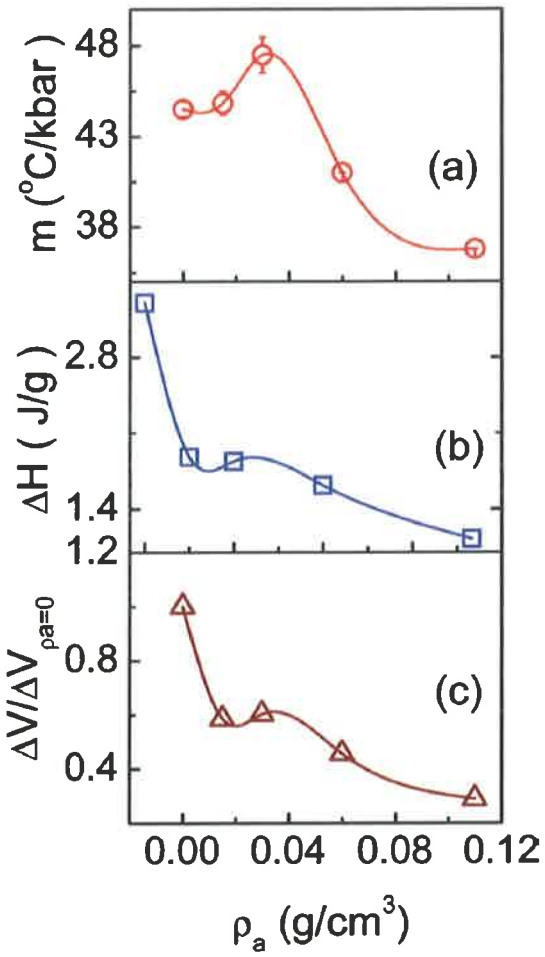


Figure 1: Variation of (a) the slope of the P-T boundary determined (b) the total enthalpy ($\Delta H = (\Delta H_{NI} + \Delta H_{RFC})$, and (c) transition volume as a function of aerosil concentration ρ_a in LC.

Phase transitions in liquid crystals in geometrically confined environment are interesting both from fundamental and technological point of view. Confinement effects are interesting because liquid crystals (LCs) (i) exhibit variety of phases with different degrees of translational and orientational order, (ii) transition are second order or at best weakly first order (iii) LCs are typical representative of soft materials (iv) response to perturbation induced by confining matrix are long ranged (v) doesn't react chemically with the host matrix. The restricted geometry can be realized by using prefabricated confining matrix such as Anopore and Nuclepore in which the voids are highly regular with well-defined pore dimensions or with biological membranes like Millipore and synpore where the large distribution of pore sizes and cavities are interconnected.

The geometrically-enforced disorder observed in these situations can also be obtained by having the liquid crystal in a network termed as aerosils formed with silica spheres of ~7 nm diameter whose surfaces are decorated to achieve hydrophilic or hydrophobic interactions. The advantage of the aerosil network is that the random disorder can be controlled and fine-tuned by simply varying the concentration of silica particles. The fragile hydrogen bond network that results from interactions between the particles permits

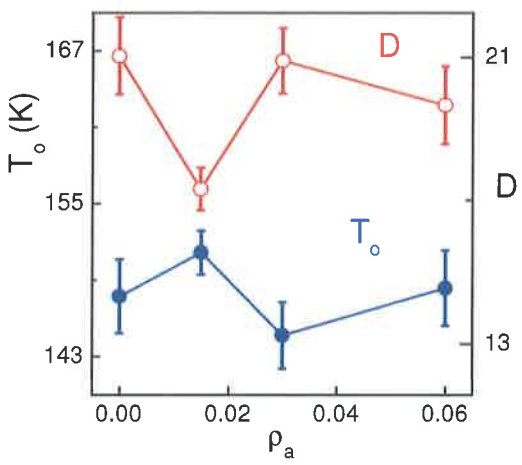


Figure 2: Non monotonic variation of glass transition temperature T_o and the fragility constant D with aerosil concentration (ρ_a)

the disorder to be created in situ, allowing the influence of the quenched randomness on various phase transitions in LC materials to be examined.

In this study, we report the effect of applied pressure on the dielectric properties of composites of a weakly polar nematic liquid crystal and its composites with Aerosil particles in the soft gel regime. The study, which is the first of its kind on nanocolloidal Aerosil systems, also has the novelty that a weakly polar nematogen is used as the host material. Differential scanning calorimetric (DSC) measurements carried out on several concentrations bring out in clear terms the double-peak profile for gels in the soft gel regime. The appearance of such a double-peak profile is associated with processes wherein the network establishes a coupling with the order parameter to begin with, but ultimately introduces distortions on the director field itself. The peak profile analysis showed that not only the temperature, but the transition enthalpy describing the two processes also, undergoes a nonmonotonic variation with Aerosil concentration. Pressure-temperature phase diagrams, in conjunction with DSC data, bring out the fact that the slope of the phase boundary and the volume jump across the nematic-isotropic transition also possess this nonmonotonic behavior. The dynamics associated with dielectric relaxation of the system remains intact even in the gels at atmospheric as well as elevated pressures, and that the activation volume decreases exponentially with temperature for the pure liquid crystal as well as for gels, with the absolute value being lower in the latter case. Detailed analysis of the temperature dependence of the relaxation frequency connected with the short axis flipping of the nematic director employing the Vogel-Fulcher-Tamann expression yields useful information regarding the influence of the Aerosil concentration on the fragility strength as well as the glass transition temperature.

This work has been published: Prasad N. Bapat, D. S. Shankar Rao, S. Krishna Prasad, and C. V. Yelamaggad, J. Phys. Chem. B, 114, 12825 (2010).

Investigator : D.S. Shankar Rao

6.6 DIELECTRIC STUDIES ON A SYSTEM EXHIBITING DEVRIES SMECTIC A-SMECTIC C* PHASE TRANSITION

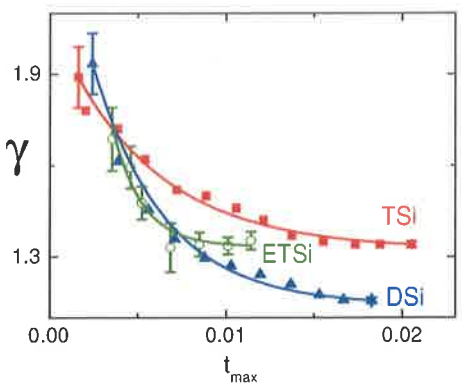


Figure 1: Dependence of the exponent γ on the temperature range t_{max} [=$(T_{max}-T_c)/T_c$, T_c is the SmA_{dV}–SmC transition temperature]. The exponent γ grows as t_{max} decreases, reaches 2D Ising model value.*

Smectic A (SmA) and smectic C (SmC) liquid crystals are layered phases possessing quasi-long-range positional order in one dimension represented by a mass-density wave, whose wavevector is either along the director (SmA) or tilted (SmC). The de Vries SmA (SmA_{dV}) phase has certain features of both the SmA and SmC structures, with the molecules substantially tilted like in SmC, but having only short-range azimuthal coherence with an averaged uniaxial order as in SmA. The chiral version of SmA_{dV} has particularly attracted a great deal of attention owing to the absence of chevron defects in display devices. We have investigated the critical dielectric behavior of three organosiloxane derivatives exhibiting the SmA_{dV} phase. In our recent investigation, we reported the novel finding of an antiferroelectric-like switching in this SmA_{dV} phase. With range-shrinking analysis, we find that the exponent describing the growth of susceptibility increases monotonically from a near-mean-field value far away from the transition to a value slightly higher than that predicted for the 2D Ising model. The latter is suggested to be due to the antiferroelectric nature of the two-layer block structure and to the change of the polar tilt angle across the transition to the smectic C* phase.

This work was carried out in collaboration with Jawad Naciri and B.R. Ratna, Naval Research Laboratory, Center of Bio/Molecular Science and Engineering, USA. This work has been published: S. Krishna Prasad, D. S. Shankar Rao, S. Sridevi, Jawad Naciri and B. R. Ratna, J. Phys.: Condens. Matter, 23, 105902 (2011).

Investigator : D.S. Shankar Rao

6.7 X-RAY DIFFRACTION STUDIES

Supramolecular liquid crystalline tris(N-salicylideneamine)s (TSANs) featuring both inter- and

intramolecular hydrogen bonding have been investigated for the mesomorphic behavior. Xray diffraction study (XRD) revealed that they self-assemble into supramolecular fluid hexagonal columnar phase with 2D hexagonal lattice over a wide thermal range.

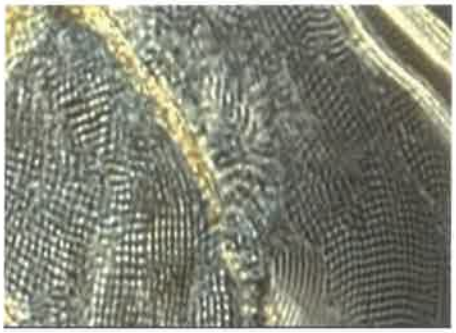


Figure 1: Polarizing optical microscopy textures observed in the TGB_C phase.*

The mesomorphic properties of 2-phenylbenzoxazole compounds having intramolecular hydrogen-bonded Schiff's base linkers have been investigated in detail using polarization optical microscope and high resolution Xray diffraction studies. All studied compounds show smectic C phase over a wide temperature range.

A new series of cholesterol-based unsymmetrical Schiff's base dimer terminated with 4-alkoxy-5-phenylthiophene have been investigated using polarizing optical microscopy and Xray diffraction studies. All the dimers exhibit mesomorphism. The dimers with long alkyl spacers (n = 10) exhibit only the N∗ phase, whereas the dimers with short alkyl spacers (n = 5) exhibit variety of phase sequence. One of the dimers showed smectic A (SmA) and N* phases whereas the other dimer displayed SmA, smectic chiral C (SmC*), N* and twist grain boundary (TGB) phases.

We report the occurrence of twist grain boundary mesophase with smectic C* blocks (TGBC*) over a very wide thermal range (100°C) in cholesterol based liquid crystalline dimers consisting of an oxadiazole unit. The range of the TGBC* phase is found to be dramatically dependent on the length of the terminal O-alkyl chain. Interestingly, these homologues, having either TGBC*-N*-BP or TGBC*-N* phase sequence, exhibit the TGBC* phase enantiotropically. The possibility of the bent structure molecule owing to the conformation dictated by the oxadiazole unit is suggested to be responsible for the observed behavior.

This work was carried out in collaboration with K. C. Majumdar, Department of Chemistry, University of Kalyani, Kalyani. This work has been published: K. C. Majumdar, P. K. Shyam, D. S. Shankar Rao and S. Krishna Prasad, J. Mater. Chem., 21, 556 (2011); Liq. Cryst. (in press DOI: 10.1080/ 02678292.2011.564662); Liq.Cryst., 37, 1539 (2010).

The mesomorphic behavior of non-disc-like oxovanadium(IV) Schiff base complexes is investigated through high resolution XRD studies. The ligands were nonmesomorphic whereas their complexes exhibited a thermally stable enantiotropic highly ordered three-dimensional plastic mesophase with a columnar structure in the extended temperature range 155–166°C. The columnar mesophases are presumed to have been built in head-to-head fashion from two half-disc-shaped molecules. Based on Spectral and Density Functional theory (DFT), a square pyramidal structure has been confirmed in the columnar plastic phase.

The mesomorphic behavior of non-discoid Liquid Crystalline Zinc(II) Schiff-Base Complexes has been investigated using XRD studies. The studies reveal that the molecules are self-organized into columnar mesophase of primitive rectangular (Col_r) and/or monoclinic oblique type.

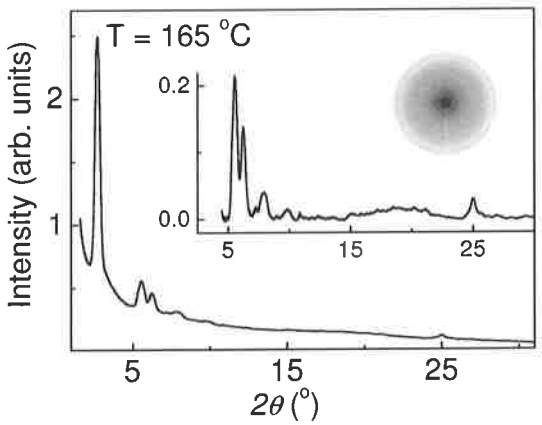


Figure 2: X-ray diffraction pattern of Zn complex at 165°C. The diffraction peaks are indexed to a columnar mesophase with primitive rectangular lattice (P222) packing.

The mesomorphic behavior of a new series of new non-discoid shaped square pyramidal oxovanadium(IV)-Schiff base complexes has been studied using XRD technique. The studies revealed that structure of the mesophase is lamellar columnar in type (Col_l). Based on DFT, spectral and magnetic studies, a square pyramidal five coordinate structure has been proposed.

New series of mononuclear lanthanide(III)-salicylaldimine complexes were investigated using Polarized Optical Microscopy (POM), Differential Scanning Calorimetry (DSC) and XRD techniques. Results show that the ligands are monotropic and their complexes exhibit enantiotropic highly viscous smectic A (SmA) mesophase. Based on the XRD results, a bilayer self organized assembly of the molecules in the mesophase are proposed.

This work was carried out in collaboration with C. R. Bhattacharjee and Gobinda Das, Department of Chemistry, Assam University, Silchar, Assam. This work has been published: C. R. Bhattacharjee, Gobinda Das, P. Mondal, S. Krishna Prasad and D.S. Shankar Rao,

Eur.J.Inorg.Chem., 1418 (2011); Inorganic Chemistry Communications (in press DOI:10.1016/j.inoche.2011.01.041); Liq. Cryst., (in press, DOI:10.1080/02678292.2011.564314); Polyhedron (in press, doi:10.1016/j.poly.2011.01.015)

Investigator : D.S. Shankar Rao

6.8 DISCOTIC LIQUID CRYSTALS

Given their potential use in a large variety of electronic devices, liquid crystalline materials are very attractive. Especially, columnar liquid crystals formed by disc like molecules, have been investigated for more than 30 years, for their potential use as electron and hole conducting properties in electronic devices such as organic light emitting diodes (OLED's), organic photovoltaic cells and field effect transistors (FETs) etc.

Our continuing interest in the design and synthesis of new discotics, which are of fundamental importance to organic material science, prompted the design and synthesis of new discotic materials.

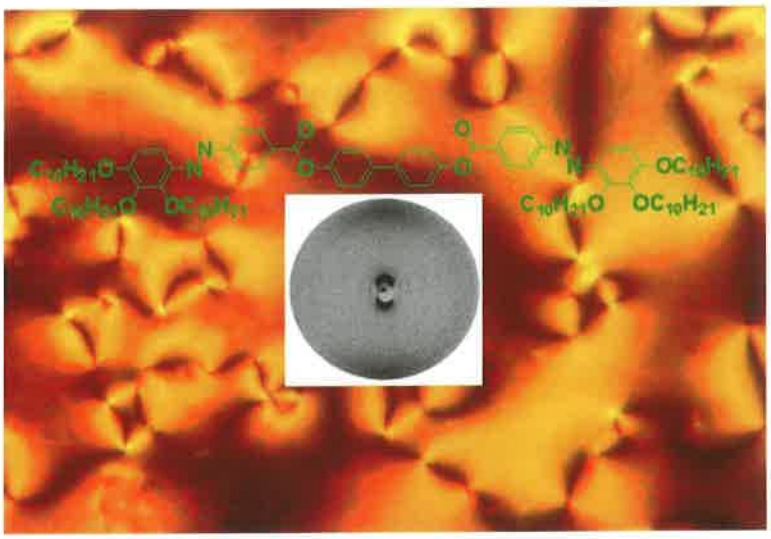
This work was carried out in collaboration with H. Monobe, Y. Shimizu from National Institute of Advanced Industrial Science and Technology, Osaka, Japan, and H. Takezoe, Tokyo Institute of Technology, Tokyo, Japan. Some of the results obtained during these investigations have been published : S.K. Varshney, Veena Prasad and H. Takezoe, Liq. Cryst., 38, 53 (2011); S.K. Varshney, H. Monobe, Y. Shimizu, H. Takezoe and Veena Prasad, Liq. Cryst., 37, 607 (2010).

Investigator : Veena Prasad

6.9 PHOTOCHROMIC LIQUID CRYSTALLINE MATERIALS

We have continued our work on this topic during this year also as these materials are of interest for photochromic reactions in liquid crystalline state. The combination of photochromic and liquid crystalline properties in the same molecule renders the material useful for several practical applications.

The insertion of various types of bulky molecular units, with photosensitivity and without destroying the mesomorphism, makes the phasmidic liquid crystals inevitable candidates for designing functional materials. Thus, we synthesised and studied the mesomorphic properties of five new series of azo functionalized phasmid-like compounds formed by covalent bonding. They consist of both symmetric and non-symmetric molecules. Most of these compounds are found to be liquid crystalline, with unusual behavior. They exhibit mainly, nematic, columnar and smectic mesophases. In addition to these phases, in few cases, we observed some higher order mesophases as well. The nature of these mesophases is investigated by polarizing optical microscopy (POM), differential scanning calorimetry (DSC) and X-ray diffraction (XRD) studies. We obtained unconventional XRD patterns for the nematic phase in these compounds, wherein the small angle and wide angle



diffractions appear in the same direction perpendicular to the applied magnetic field and accounting only for half the length of actual molecule. Based on the experimental results, we propose a model for the molecular arrangement in the columnar phase as center rectangular. Dielectric and optical transmission measurements in the mesophases of one representative compound are also reported. We have carried out qualitative investigation on photosensitivity of the mesophases of one of these compounds.

This work was carried out in collaboration with Meenal Gupta and Arun Roy, Raman Research Institute, Bangalore. Some of the important results that we obtained during these

investigations are published: N.G. Nagaveni, Meenal Gupta, Arun Roy and Veena Prasad, J. Mater. Chem., 20, 9089 (2010).

Investigator : Veena Prasad

6.10 BIAXIAL NEMATIC MATERIALS

We are continuing our probe into various physical parameters to establish the exact nature of the biaxial nematic phases exhibited by the two azo substituted bent-core materials that are designed and synthesized in our laboratory. Thus, Polarized Raman spectroscopy was used to investigate the development of orientational order and the degree of phase biaxiality in one of these systems, A131. The results indicated a second order transition from the uniaxial to biaxial nematic phase.

This work was carried out in collaboration with M. S. Park, B-J. Yoon, J. O. Park, M. Srinivasarao, Georgia Institute of Technology, Georgia, USA and Satyendra Kumar, Kent State University, Kent, USA. The important results that were obtained during these studies have been published in the journal: Min Sang Park, Beom-Jin Yoon, Jung Ok Park, Veena Prasad, Satyendra Kumar and Mohan Srinivasarao, Phys. Rev. Lett., 105, 027801 (2010).

Investigator : Veena Prasad

6.11 SUPRAMOLECULAR TRIS(N-SALICYLIDENEAMINE)S: SYNTHESIS AND CHARACTERIZATION

Supramolecular liquid crystalline tris(*N*-salicylideneamine)s (TSANs) featuring both inter- and intra-molecular hydrogen bonding have been synthesized and characterized for the first time. These TSANs formed by condensing three equivalents of 3,4,5-trialkoxy-benzoylhydrazine with 1,3,5-triformylphloroglucinol exist as the single C_{3h}-symmetric *keto-enamine* product solely, unlike the previously reported TSANs. The optical microscopic (Figure 1a), calorimetric and powder X-ray diffraction (Figure 1b-c) techniques established their self-assembly into supramolecular fluid hexagonal columnar (Col_h) phase (Figure 1d) over a wide thermal range. The intermolecular H-bonding and π-stacking are the key factors that favor their self-assembly into fluid Col structure. The former feature is especially significant in improving thermal range

of the Col phase. The non-emissive nature of these materials indicates that the self-complementing arms present around the central C_3 core aid in suppressing π-conjugation effectively. This work therefore serves to support the emerging notion that the structural features and material properties of TSANs can be readily altered by subjecting them to simple chemical transformation such as substituting the central core with appropriate functional wings.

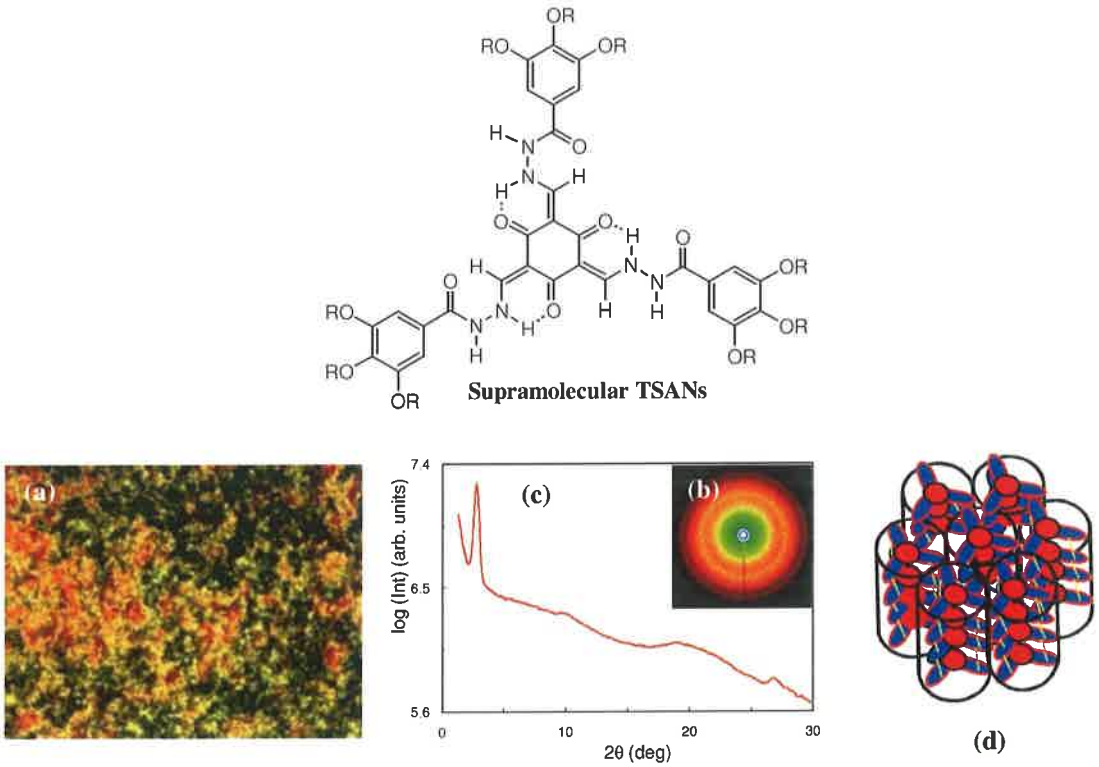


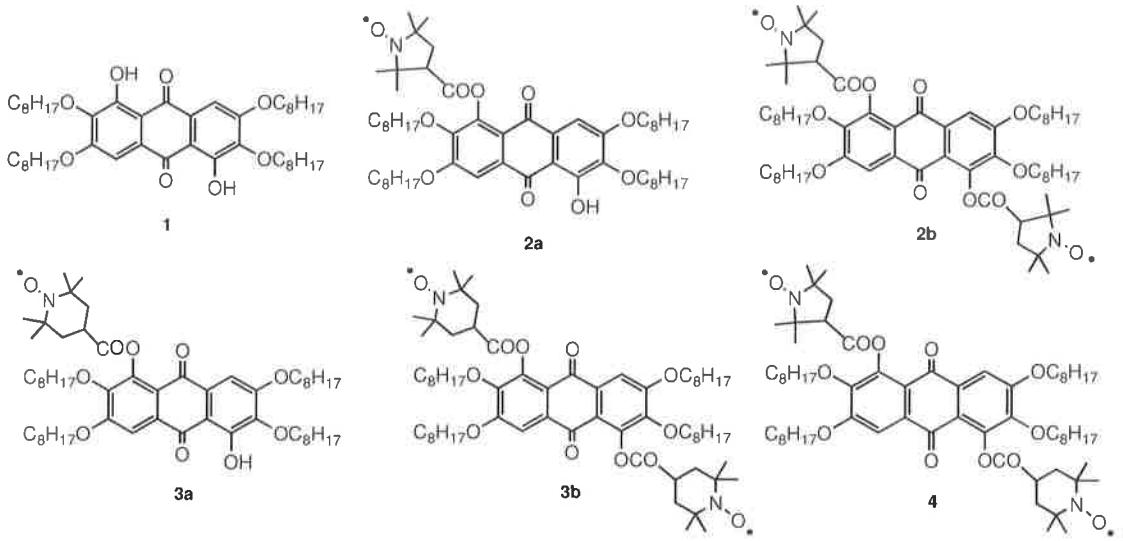
Figure 1. Microphotograph of the texture (a), XRD pattern (b) and 1D-intensity vs 2θ profile (c) obtained for the Col_h phase of a TSAN having C_{12} terminal tails. (d) Schematic representation of the Col_h phase where the individual columns are formed by the self-assembly of C_{3h} TSANs through H-bonds.

Investigator : C.V.Yelamaggad

6.12 ORGANIC RADICALS DERIVED FROM ANTHRAQUINONE: SYNTHESIS AND CHARACTERIZATION

A number of novel tetraalkoxy-substituted anthraquinones (1, 2a-b, 3a-b and 4) differing in the number and nature of nitroxide radicals have been prepared and characterized. The Japanese collaborators have investigated their electrochemical behaviour. It is found that they exhibit electrochemical (redox) activity and paramagnetic behaviour. Of the two radicals investigated for their stable multi-step discharging process, the mono-substituted PROXYL compound appears to be relatively promising when compared to its disubstituted analogue

suggesting that the increase in the number of radical moieties has no added advantage in the discharging process. Besides, the mono-substituted PROXYL radical shows a heat-responsive magnetic property. Thus, our study reveals that anthraquinone-based radicals are interesting molecular systems and deserve further investigation to elucidate their structure-property correlations.



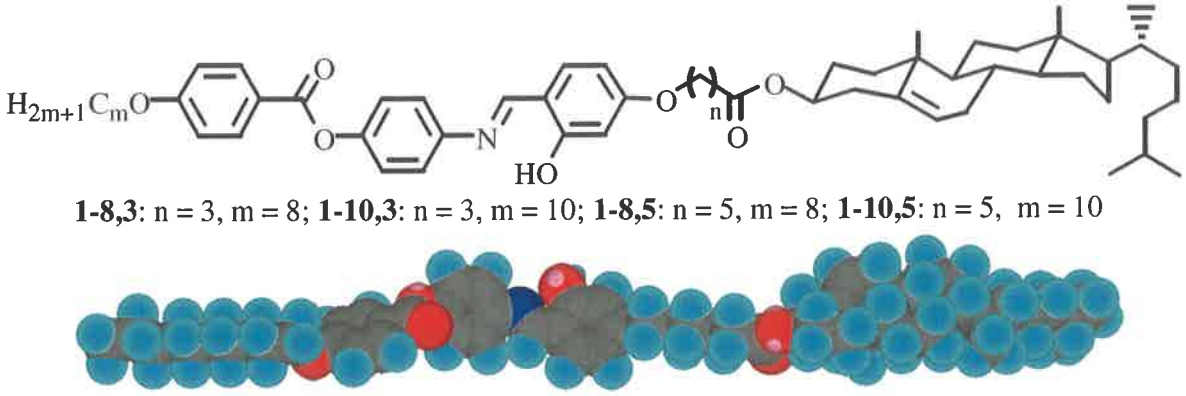
This work was carried out in collaboration with H. Akutsu, J. Yamada, M. Satoh and S. Nakatsuji, Graduate School of Material Science, University of Hyogo, Japan.

Investigator : C.V.Yelamaggad

6.13 CHOLESTEROL-BASED LIQUID CRYSTAL DIMERS: SYNTHESIS AND MESOMORPHISM

Several nonsymmetric optically active dimers comprising a three ring salicylaldimine core, substituted with an *n*-alkoxy tail, and cholesterol unit separated by an even-parity ω-oxyalkanoyloxy spacer have been synthesized and evaluated for their mesomorphism. A general molecular structure of these newly prepared dimers (1-8,3 , 1-10,3 and 1-8,5 and 1-10,5), are shown in Fig. 1. These dimers display a complex and highly frustrated mesophase, namely the twist grain boundary (TGB) phase possessing chiral smectic C (SmC*) blocks, denoted as the TGBC* phase, over an exceptionally wide (105 -150 °C) thermal range; the existence of this frustrated phase has been unambiguously evidenced by optical (Fig. 2a-c), calorimetric, spectroscopic (Fig. 2d), He-Ne laser (Fig. 2e) and X-ray (Fig. 2f) diffraction studies. The occurrence of this mesophase over such a wide thermal range is remarkable in view of

the very complex and frustrated nature of the TGBC* phase. It may be assumed that the extended rod-like geometry, enantiomeric excess and the strong chirality of the molecules combine to produce this interesting thermal behaviour.



1-8,3: n = 3, m = 8; **1-10,3**: n = 3, m = 10; **1-8,5**: n = 5, m = 8; **1-10,5**: n = 5, m = 10

Figure 1. A general molecular structure of chiral dimers. The space-filling model of the energy minimized structure of an optically active dimer 1-10,5 is given as representative case; notice the elongated and rigid rod-like conformation of the dimer.

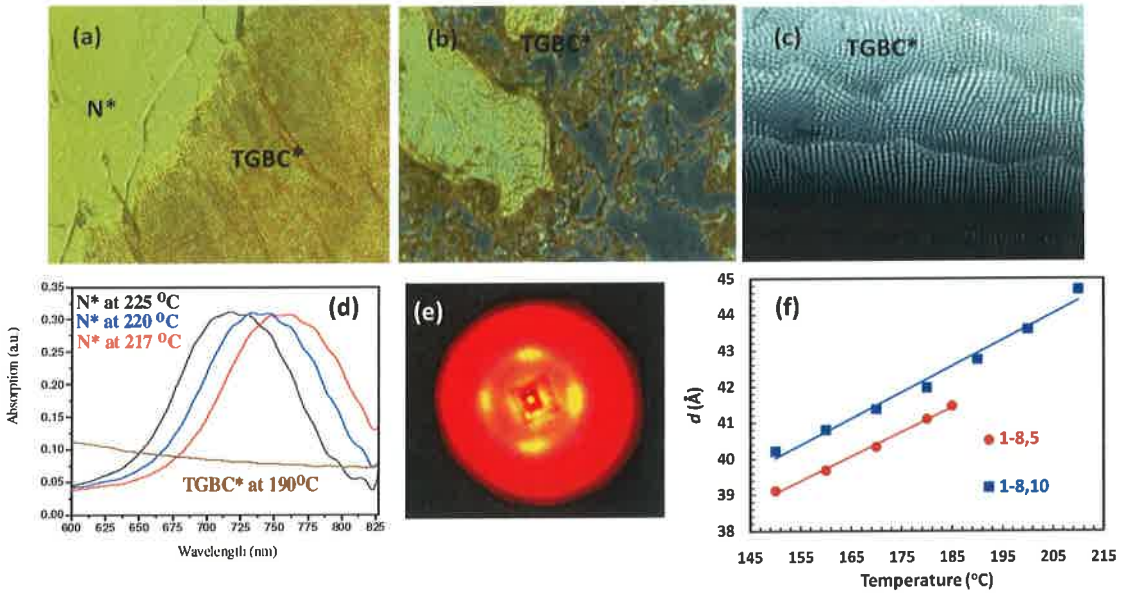


Fig. 2 (a-c) Optical microscopic textures seen for the mesophases of 1-8,3 : (a) the square grid texture (RHS) of the TGBC phase as seen growing from the N* phase (see LHS) and (b) co-existence of square grid pattern and undulated filaments of the TGBC* phase; (c) square grid pattern superposed on the Grandjean Cano lines of the planarly aligned TGBC* phase in a wedge-type cell. (d) The UV-Vis spectra obtained for the planarly-aligned N* and TGBC* phases of dimer 1-10,5. (e) The He-Ne laser beam diffraction pattern obtained from the TGBC* phase of dimer 1-10,5. (f) The layer spacing (d) as a function of temperature obtained in the TGBC* phase for the dimers 1-8,5 and 1-8,10.*

This work was carried out in collaboration with Girija M. Sonar, MES College, Bangalore.

Investigator : C.V.Yelamaggad

6.14 SYMMETRY BREAKING OF ANION AT THE AIR-WATER INTERFACE

Many liquid state processes, chemical reactions, transport process and ion channels in membranes involve ion-solvent interactions. Interfaces play a crucial role in these processes. Though air-electrolyte interface is the simplest system, much is left to be addressed and it still attracts lot of attention. Recent experiments and simulations on the ions indicate their presence at the air-water interface with a non-monotonic concentration profile contradicting the textbook description of the depletion of ions. Nonlinear infra-red–visible sum frequency spectroscopy (IVSFS) is a versatile technique which is inherently surface specific due to lack of centre of symmetry. Under the electric dipole approximation, the sum frequency intensity is given by,

$$I_{sf} \propto \left|\chi_{nr}^{(2)} + \sum_q \frac{A_q}{\omega_{ir} - \omega_q + i\Gamma_q}\right|^2 I_{vis} I_{ir}$$

Where, $\chi^{(2)}_{nr}$ represents second order complex non-resonant susceptibility,

A_q is the amplitude of the resonant vibration, ω_{ir} and Γ_q are the resonant frequency and the damping constant of the q-th mode, respectively.

In general, the ions residing at the air-water interface are assumed to have least distortion in their symmetry. However, factors like the location of the ion at the interface, its polarizability, size and the interaction of ions with the solvent may potentially lead to reduction in symmetry.

We have employed IVSFS technique to investigate the aqueous solution of potassium ferrocyanide. Ferrocyanide anion possesses octahedral symmetry (O_h). To observe a vibrational mode under sum frequency spectroscopy, the selection rule predicts that it should be both infra-red and Raman active. Applying this selection rule to ferrocyanide anion

predicts that it is sum frequency *inactive*. Interestingly, IVSFS studies carried out by us on aqueous solution of potassium ferrocyanide not only shows the affinity of this anion to the interface but also provide spectroscopic evidence for the reduction in symmetry.

We are systematically investigating the dependence of ion and the solvent features on concentration. This work is currently in progress.

This work is done in collaboration with Dr. Peter Karagerogiev and Prof. Hubert Motschmann, University of Regensburg, Regensburg, Germany.

Investigator : P. Viswanath

6.15 INFLUENCE OF CATIONS ON THE LANGMUIR MONOLAYER OF MESOGENIC MOLECULES

Understanding electrostatic interactions of ions with the head group is quite important in the context of bio-mineralization, crystallization and also in many biological processes. Langmuir monolayer are ideal systems for such studies since the electrostatic interactions can be tuned by varying the pH, valence and also the concentration of ions in the sub-phase.

We have undertaken an investigation to understand the interaction of cations with the polar head group of mesogenic molecules which can influence the two dimensional mesophases, stability, texture and morphology. In literature, spectroscopic and polarizing optical microscopy studies provide evidence for the interaction of the cation with the polar head group. The cation coordination with the head group has a dramatic change in the orientational response and also the anchoring properties of the molecules at the interface.

We are studying the influence of cations on the Langmuir monolayer of mesogenic molecule, octyl cyano biphenyl, at the air-water interface. Further, to gain insights into the viscoelastic properties, we are employing magnetic needle interfacial shear rheology experiments on these systems. This work is currently in progress.

Investigator : P. Viswanath

6.16 EFFECT OF POLYMER COATING ON THE MAGNETIC PROPERTIES OF OXYGEN-STABILIZED NICKEL NANOPARTICLES

The structural and magnetic properties of polymer coated (pc-) and uncoated (uc-) Ni nanoparticles prepared by chemical reduction method have been studied in this work. Both samples have been identified to have a tetragonal crystal structure, different from its usual fcc structure, though some traces of fcc-Ni phase have been observed in x-ray diffraction and selected area electron diffractogram patterns for pc-Ni. This structural modification of fcc-Ni occurs due to the presence of interstitial oxygen atoms in the Ni lattice and results in appreciably modified magnetic properties in this new phase of Ni, as, for example, a non-hysteretic magnetization response with applied field at 300 K. The ZFC/FC and ACS plots reveal the occurrence of two magnetic transitions at 60 and 20 K in the pc-Ni sample and only the former transition in the sample has the features that are reminiscent of cluster freezing/blocking and attributed to small fcc-Ni core while the low-temperature transition is entirely due to the structure and composition of the oxygen-stabilized tetragonal Ni NPs. The magnetic transition observed at 20 K has been related to a PM to FM-like phase transition though there is no evidence of a long-range FM order. This can also be attributed to the cooperative freezing of FM clusters. The comparative study of the magnetic properties of uc- and pc-Ni particles exemplifies the role played by the PVA matrix in modifying the magnetic properties of the uc-Ni sample.

This work was carried out in collaboration with Prof. V. Srinivas, IIT Kharagpur and Prof. Je-Geun Park, Seoul National University, Korea.

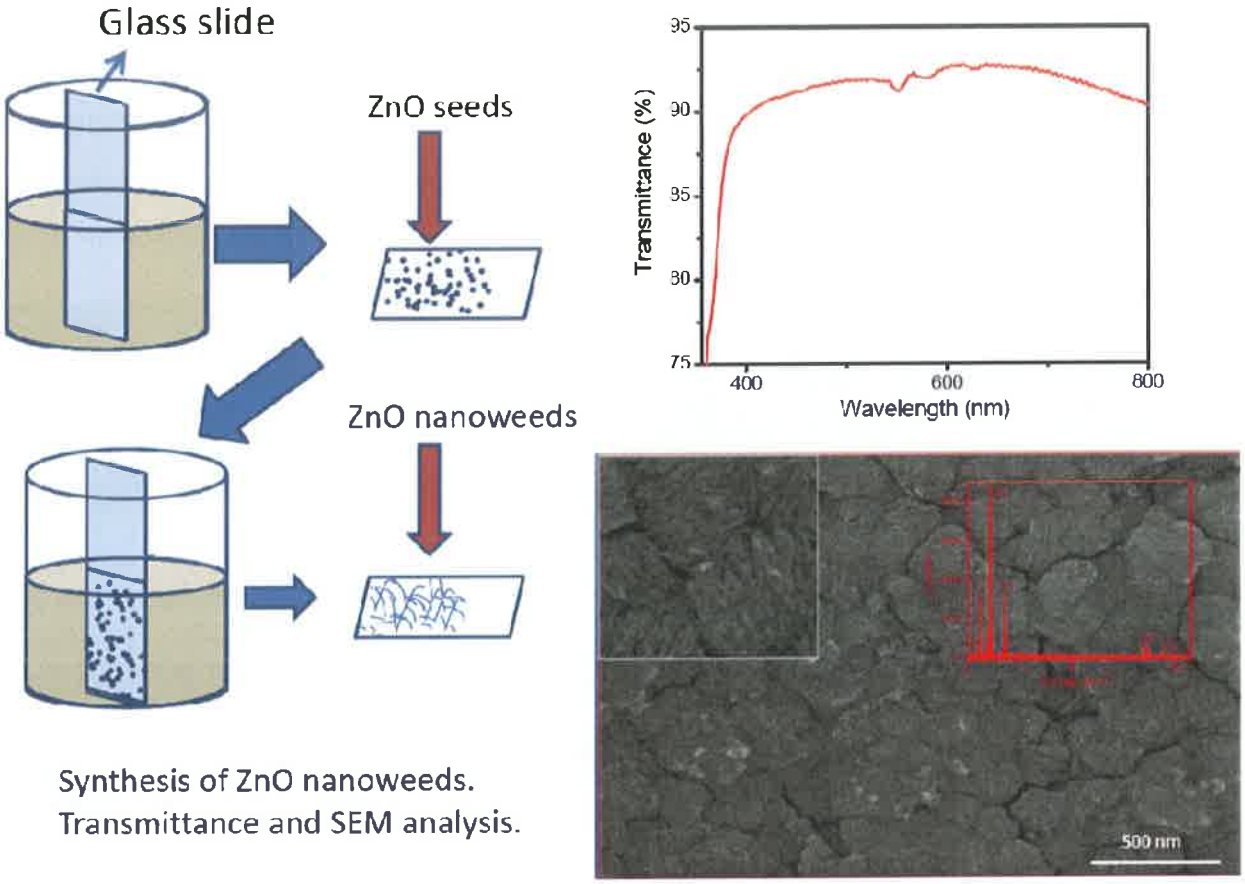
Investigator : S. Angappane

6.17 GROWTH OF ZINC OXIDE NANOWEEDS

ZnO films of nanoweeds morphology have been synthesized by a chemical method. This method involves preparation of ZnO thin films, which acts as seeds, on glass and quartz substrates by dipping in solution of 0.005 M zinc acetate hydrate in ethanol. The substrates were repeatedly dipped in the solution and dried with argon gas after each coating.

The deposited ZnO films were heated to 350 °C. These seeded substrates were further immersed in aqueous solution containing 25 mM of zinc nitrate hydrate and 25 mM of hexamethylenetetramine and 5-7 mM of polyethylenimine. The solution was maintained at

92°C for 12 hours and then rinsed with deionized water. Finally the films were annealed in air at 400 °C for 30 mins. The obtained ZnO films were characterized using x-ray diffraction (XRD), UV-Visible spectroscopy and scanning electron microscopy (SEM). The XRD confirms the



Synthesis of ZnO nanoweeds.
Transmittance and SEM analysis.

crystallinity of the obtained ZnO films. The SEM shows the nanoweeds morphology and it is found to show transmission as high as 92 %. These ZnO films of nanoweeds morphology are being studied for device applications, such as solar cells and photodiodes.

Investigator : S. Angappane

6.18 SYNTHESIS OF ZnO NANORODS

We have synthesized ZnO nanorods on glass and silicon substrates by sol-gel method at 90°C. Firstly ZnO seeds were formed on substrates by dipping in the aqueous solution of zinc acetate hydrate of 0.01 M and heated for a minute at 90 °C. Consequently growth of ZnO

nanorods was achieved by immersing the seeded substrates in the solution containing 0.05 M of zinc nitrate hexahydrate and hexamethylenetetramine kept at 90 °C for about 12 hours.

The figs. 1 and 2 show the scanning electron micrographs (SEM) displaying the growth of flowerlike structures composed of ZnO nanorods on glass and silicon substrates respectively. The ZnO nanorods are of varying size evident on the glass substrates, whereas those on the Si substrate are of uniform size. Each of the rods has one end outside and another end bound to

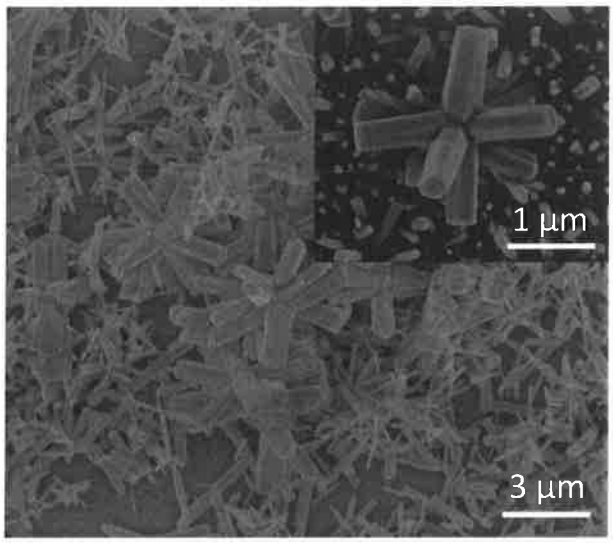


Fig. 1

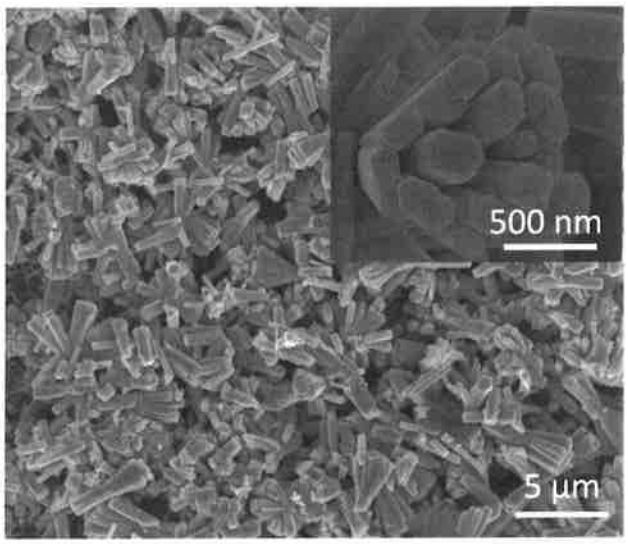


Fig. 2

SEM images of ZnO nanorods grown on glass and silicon substrates

other rods. The insets show the well branched nanorods which terminates with hexagonal facet. ZnO rods have an average diameter of about 200-300 nm and lengths up to a few micrometers. The x-ray diffraction data of both the samples indicates the polycrystalline nature of the ZnO nanorods. Nevertheless the growth of the nanorods is expected to be along the c-axis. Further work is being carried out to study the electrical transport and optical properties of these ZnO nanorods.

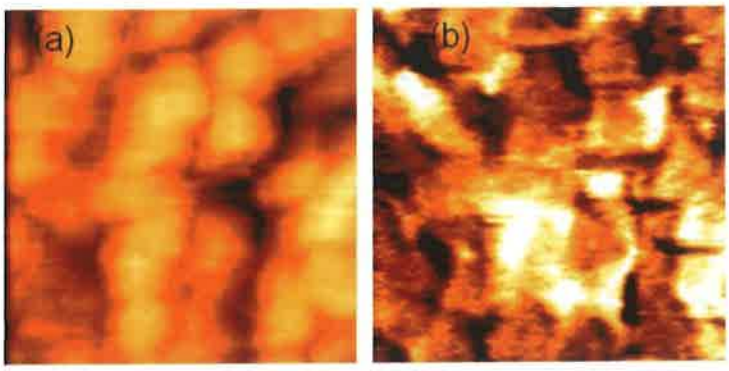
XRD and SEM measurements were carried out at JNCASR, Bangalore in collaboration with Prof. G. U. Kulkarni.

Investigator : S. Angappane

6.19 INVESTIGATION OF FERROELECTRIC DOMAINS IN LEAD MAGNESIUM NIOBATE-TITANATE THIN FILMS EMPLOYING SCANNING PROBE MICROSCOPY.

Thin films of composition $0.85PbMg_{1/3}Nb_{2/3}O_3–0.15PbTiO_3$ (0.85PMN–0.15PT), a relaxor ferroelectric, were grown on $La_{0.5}Sr_{0.5}CoO_3$/(111)Pt/TiO_2/SiO_2/Si substrate by pulsed laser deposition at different oxygen partial pressures. All the films possess a perovskite structure with rhombohedral phase. XRD and SEM characterizations revealed that the oxygen pressure has profound impact on the orientation and morphology of the grains. The effect of deposition oxygen pressure on the ferroelectric domains of PMN-PT thin films was studied by dynamic-contact electrostatic force microscopy (DC-EFM). DC-EFM detects the electric field caused by surface polarization charge density under a modulating ac electric field in the contact mode. Autocorrelation analysis has been performed on the acquired domain images and the surface polarization correlation length is found to increase (ie. polarization disorder decrease) with increase in oxygen pressure up to 0.3 torr. This is attributed to the oxygen vacancies creating internal electric field variations giving rise to polarized regions in low oxygen pressure deposited films (0.1 and 0.2 torr). The oxygen vacancies and grain boundaries also exert domain wall pinning resisting polarization switching in applied electric field. A bias induced polarization switching is found in higher oxygen pressure deposited films (0.3 and 0.4 torr) that takes place by the nucleation of new domains and subsequent domain wall expansion. The film deposited at 0.4 torr presents a unique case with triangular shaped grains and higher polarization disorder.

This work was carried out in collaboration with D. Saranya, S. B. Krupanidhi, Indian Institute of Science, Bangalore.



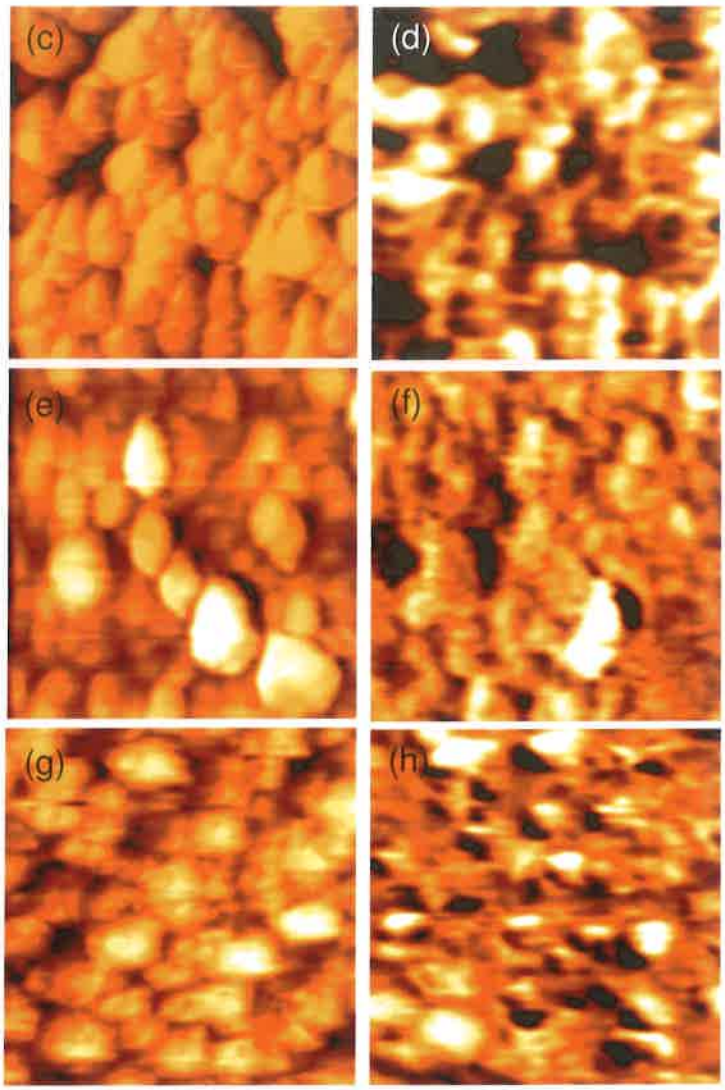


Figure 1: Topography and domain images of 0.85PMN–0.15PT films deposited at various oxygen partial pressures, simultaneously acquired by DC-EFM at 4 V, 17.8 kHz ac. Left column presents topography and right column, domain images. Bright and dark contrasts in the domain images correspond to polarizations in opposite orientations. (a), (b) 0.4 torr, image size–500 nm×500 nm. (c), (d) 0.3 torr. (e), (f) 0.2 torr. (g), (h) 0.1 torr. Image size in (c), (d), (e), (f), (g), (h) is 1 μm×1 μm.

Investigator : Neena Susan John

6.20 STRESS-STRAIN RELATION IN THE COLLAPSE OF LANGMUIR MONOLAYER OF A DIMER OF DISK SHAPED MOIETY

Langmuir monolayer at air-water interface can be compressed from a uniform condensed phase to a collapsed state wherein the molecules go into the third dimension. It is known that the condensed monolayer can collapse by forming three-dimensional (3D) crystallites or by forming multilayers. Although the physical properties of a material in two-dimensional (2D) system can be different from the bulk, the concepts developed to describe the bulk materials

can be extended to describe the properties of 2D systems. For example, in the study of monolayer rheology, the bulk continuum concepts has been applied to two-dimensional monolayers. Similarly, using constitutive equations based on the stress-strain models of bulk solids, Kampf and others related the experimental parameters in the collapsed regime of an insoluble monolayer. We have studied the monolayer of a novel dimer of disk shaped triphenylene moiety, terephtalic acid bis-[6-(3,6,7,10,11-pentahexyloxy-triphenylen-2-yloxyl)-hexyl] ester (tp-dimer) at air-water interface. It is known that the molecules with such moieties can take either face-on or edge-on configuration at air-water interface depending on the area per molecule and surface pressure. In the edge-on configuration, the molecules can assemble into columns with column axis parallel to the interface. Such films transferred onto solid substrates are of importance as they have high degree of anisotropy in conductance and can behave like one dimensional conductors which have potential applications.

The monolayer of tp-dimer at air-water interface exhibited coexistence of condensed and gas phases at large area per molecule which on compression transformed to a uniform condensed phase at lower area per molecule (1.80 nm^2) and then collapsed at 1.67 nm^2. The monolayer film transferred by Langmuir–Blodgett (LB) technique onto a hydrophilic silicon substrate was studied using an atomic force microscope. The topography image (Figure 1) showed the film to be of height of about 1.5 nm corresponding to the edge-on configuration of the triphenylene moieties (Figure 2). The studies on the collapse of monolayer at air-water interface as a function of compression rate and temperature showed that the collapse pressure increased with increase in the compression rate. The surface pressure of the monolayer is considered as stress and compression as strain. The strain rate is related to the collapse pressure by a power law similar to that found in dendrimers (Figure 3). The studies on the effect of temperature on collapse pressure of tp-dimer monolayer showed that the collapse pressure decreased with increase in temperature.

We have analyzed the data by using the bulk constitutive equations and considering the Arrhenius temperature dependence of the strain rate. The analysis yielded an activation energy of 158.6 kJ/mol for collapse of the monolayer. Our studies on the collapse mechanism indicated that the collapse of tp-dimer monolayer is through the formation of nuclei of 3D crystallites.

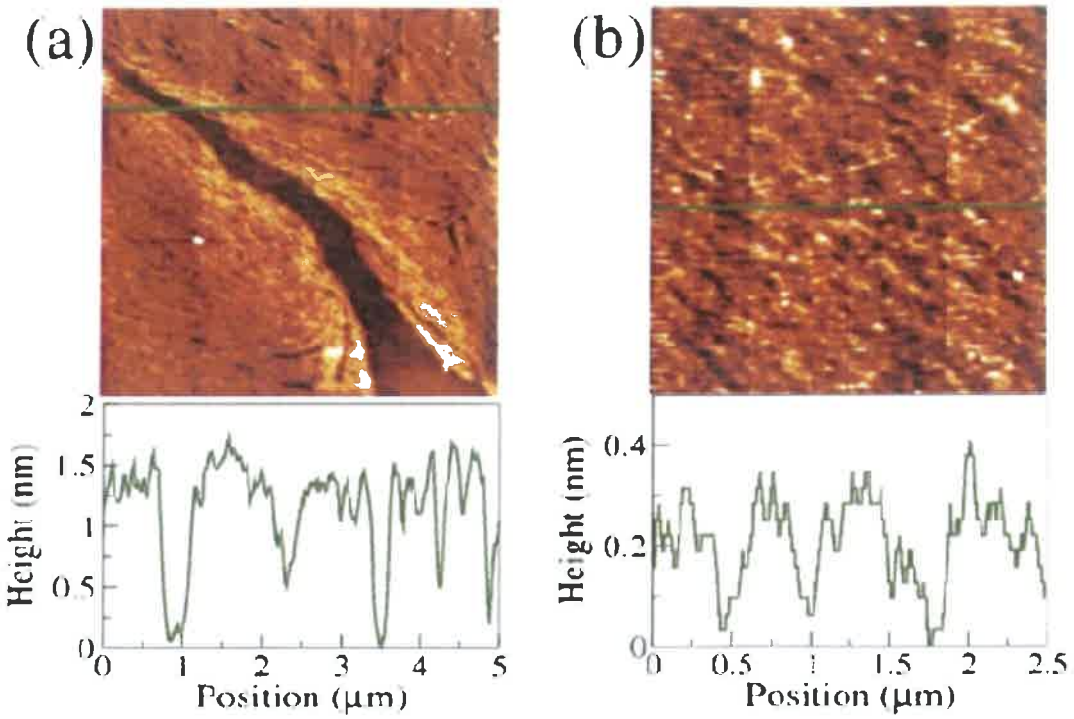


Figure 1: (a) AFM image of the LB film of tp-dimer on a hydrophilic silicon substrate. The line profile yields an average thickness of the film to be 1.5 nm. (b) AFM image of a bare hydrophilic silicon substrate. The line profile yields the rms roughness less than 0.4 nm.

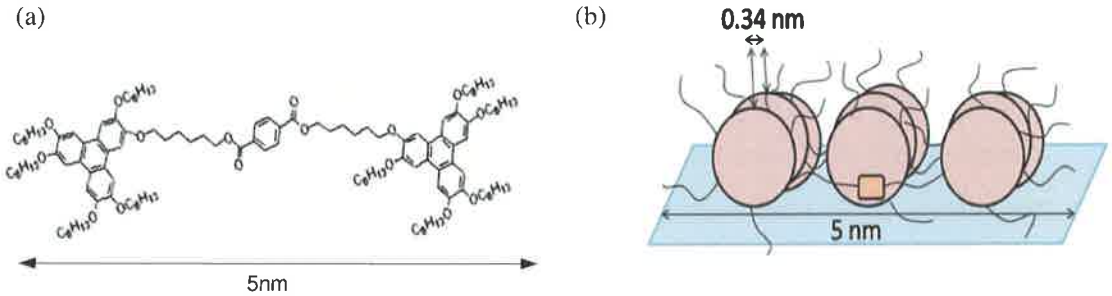


Figure 2: (a) Molecular structure of tp-dimer. (b) Schematic diagram showing the organization of the tp-dimer molecules with the triphenylene moieties in the edge-on configuration. The estimated molecular area for this configuration is about 1.7 nm^2.

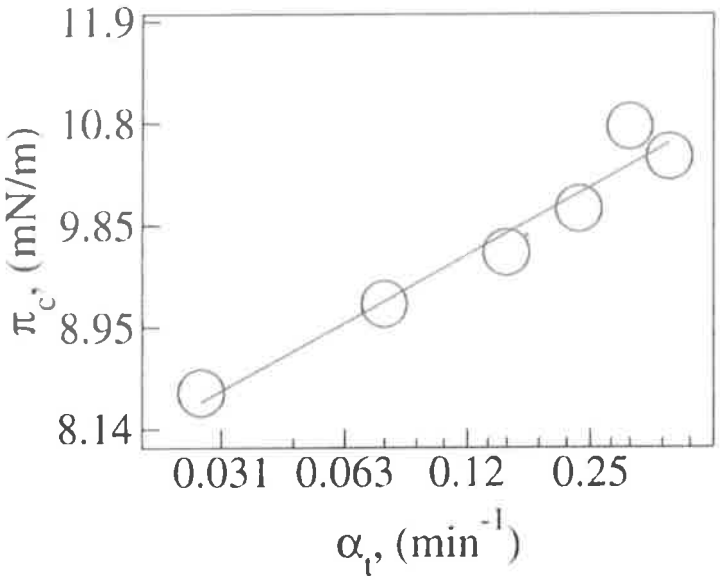


Figure 3: Variation of collapse pressure (π_c) as a function of strain rate (α_t) for tp-dimer monolayer at 25 °C. The open circles represent the experimental data and the solid line represents the power law fit ($\pi_c = C1\,\alpha_t^{1/n}$) to the data points.

This work was carried out in collaboration with Bharat Kumar, Satyam K. Gupta and Sandeep Kumar, Raman Research Institute, Bangalore. This work has been published: Bharat Kumar, K.A.Suresh, Satyam K.Gupta and Sandeep Kumar, *The J. of Chem. Phys.*, 133, 044701 (2010).

Investigator : K. A. Suresh

6.21 MULTIPLE ELECTROCONVECTION SCENARIOS IN A BENT CORE NEMATIC LIQUID CRYSTAL

This study concerns the anisotropic electrohydrodynamic states formed over a wide temperature range (~45 °C) in a planarly aligned bent core nematic liquid crystal driven by fields of frequency in the range 0.1 Hz-1 MHz. Three different primary bifurcation scenarios that involve both standard and nonstandard instabilities are generated in the voltage-frequency (*V–f*) plane, depending on the temperature *T*. These, under increasing *T*, are characterised by the pattern sequences (i) inplane longitudinal rolls (ILR)→inplane normal rolls 1 (INR1); (ii) Williams rolls (WR)→ILR→INR1; (iii) WR→INR2→INR1. Temperature induced ILR→INR2 transition, the first example of its kind, points to elastic anisotropy as possibly the determining factor in wave vector selection. In the ILR and INR states, at threshold, the director modulations are predominantly azimuthal, and the streamlines, mainly normal to the

wave vector, in the sample plane. Well above threshold, growing director deviations lead to narrow disclination loops that evolve in regular arrays, their area density being exponential in voltage. The defects drift in a coordinated manner along the flowlines with a speed that scales

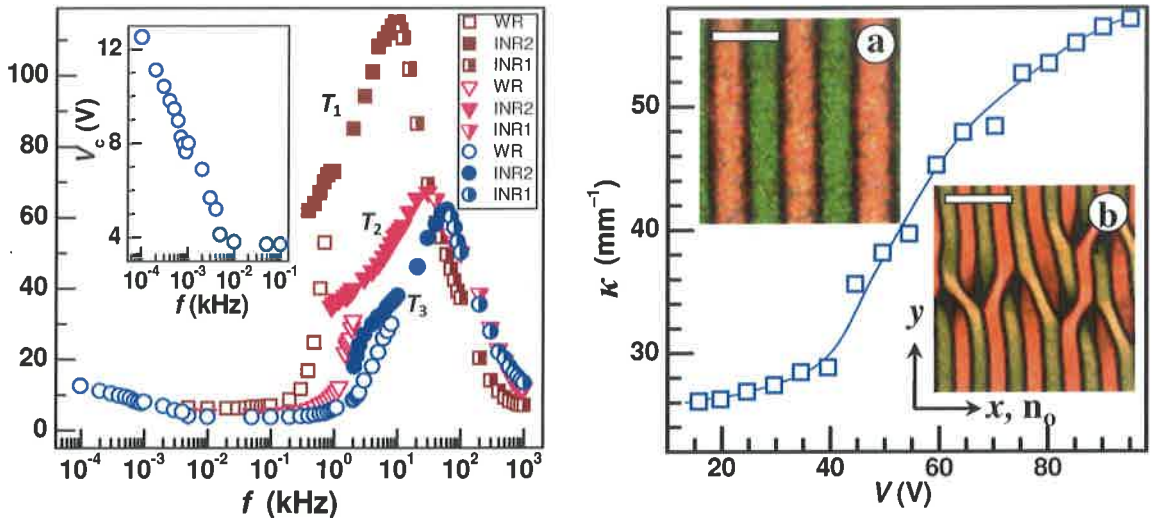


Figure 1: (Left) The critical voltage V_c for the primary bifurcation as a function of frequency f. Squares, triangles and circles correspond, respectively, to temperatures T_1=100 °C, T_2=110 °C and T_3=120 °C. The inset is an enlargement of the low frequency region of the plot for T_3. (Right) Wave number of the INR1 pattern as a function of applied voltage in a 15.5 μm thick sample; 50 kHz, 80 °C. Inset: Patterns observed under crossed polarizers slightly inclined to (x, y), in the INR1 state at 80 °C. (a) Vertical stripes showing the difference in azimuthal director deviation in adjacent stripes; 50 kHz, 1.7 V_c. (b) Same as (a), except for V=6 V_c, showing arrays of edge dislocations. Bar 40 μm.

nonlinearly with voltage; they mediate in the eventual occurrence of turbulence. The current theories of anisotropic convection based on *static* electrical parameters fail to account for the observed high frequency instabilities. The study includes (i) a quantitative characterization of the critical parameter functions $V_c(f)$, $V_c(T)$, $q_c(f)$ and $q_c(T)$, q_c denoting the critical pattern wave number, and (ii) measurement of electrical and elastic parameters of relevance to electroconvection; the latter show anomalous features such as inversion of dielectric and conductivity anisotropies, and larger splay elastic modulus relative to bend, which are explicable assuming the presence of smecticlike short range order in the nematic phase of the bent core compound.

This work was carried out in collaboration with W. Weissflog, Martin-Luther-Universität Halle, Institut für Physikalische Chemie, Halle (Saale), Germany.

Investigator : K. S. Krishnamurthy

6.22 TWIST DISCLINATION LOOPS IN A BENT-CORE NEMATIC LIQUID CRYSTAL

The generation and stability of half-strength twist disclination loops separating planar and π-twisted regions in a bent-core nematic liquid crystal with planar anchoring has been investigated. Loops L(P) and L(T) surrounding planar and π-twisted domains, respectively, are both generated during relaxation from the quasi-homeotropic splay-Freedericksz state. It is

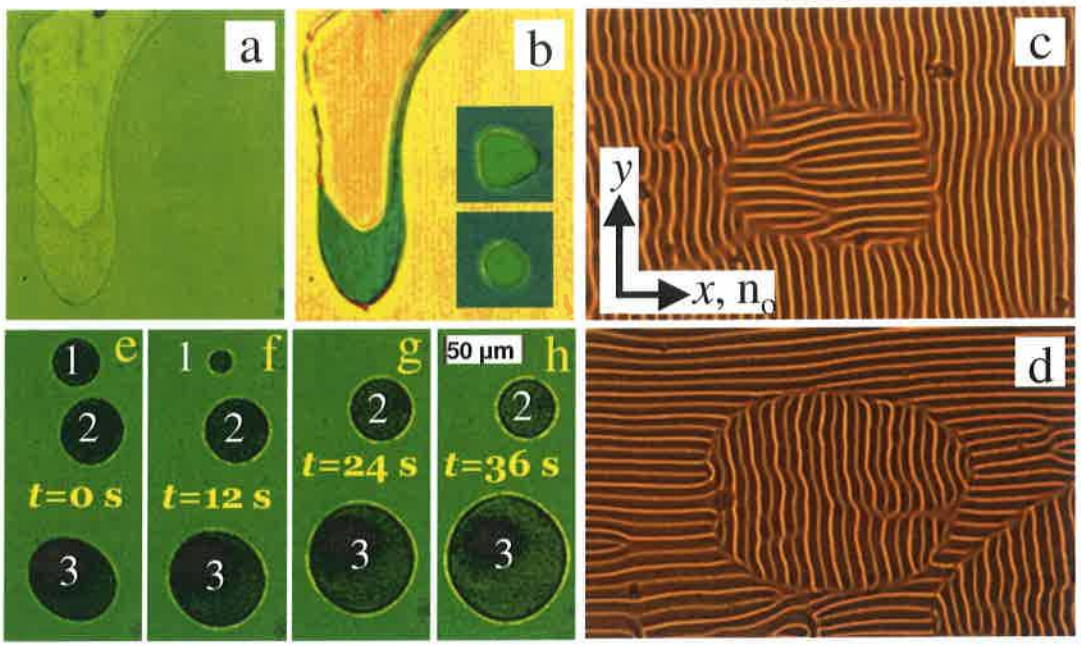


Figure 1: (a) Disclination lines from pincement of a wall; 15 V, 10 kHz. (b) Same region as in (a) soon after switching the field off; the greenish region is in the process of developing a π-twist; the insets, recorded a few seconds apart after the birefringence colours in the twisted (bright green) and untwisted (dark green) became steady, show the tendency of the twisted domain to become circular. (c,d) Electroconvection rolls of the conduction regime enabling identification of planar and π-twisted regions; 20 kHz, ~9.0 V, 115 °C. In (c), the rolls are normal to the director $\mathbf{n}_o$ in the surrounding planar region and along $\mathbf{n}_o$ in the π-twisted island, with the two regions separated by a |s|=1/2 normal twist loop. In (d), the situation is the reverse, leading to an inverse loop. (e-h)Three half-strength twist disclination loops between planar and surrounding π-twisted regions in different dynamical states at times t after removal of the field. Loops 1, 2 and 3 are subcritical, quasi-critical and supercritical, respectively. Diagonally crossed polarizers. 130 °C. d= 12.14 µm. 5 µm scale div.

found that the metastable twisted state occurs as a rule in the region of lateral separation of singular loops formed via wall pincement and collapsing at different rates. The director patterns at different levels of electrical excitation are analysed to understand how the separation of wedge lines may bring about the twist in the field-off state. Loops L(T) shrink monotonically in accordance with the power law $R \propto (t_o - t)^{\alpha}$ and disappear at time t_o; significantly, the exponent is itself a function of the radius R, as previously predicted. For the circular loops L(P), there exists a critical radius R_c separating regimes of growth and decay. R_c varies with temperature indicating its dependence on elastic anisotropy. R, which changes quasistatically around R_c, is linear in time in the long thread limit. The earlier Sonnet-Virga model for L(T) is extended for L(P) to fully account for the observed dynamics of both subcritical and supercritical loops, and also to extract the related viscoelastic parameter. Finally, it is shown that the 'electrical quenching' process may also produce 2π-twisted domains and a variety of disclination lines between variously aligned regions.

The experimental part of this work was carried out in collaboration with W. Weissflog, Martin-Luther-Universität Halle, Institut für Physikalische Chemie, Halle (Saale), Germany; and the theoretical part, in collaboration with A. M. Sonnet, Department of Mathematics and Statistics, University of Strathclyde, Glasgow G1 1XH, Scotland, UK and E. G. Virga, Dipartimento di Matematica, Università di Pavia, via Ferrata 1, I-27100 Pavia, Italy.

Investigator : **K. S. Krishnamurthy**

7. SPONSORED PROJECTS

- An Indo-Bulgarian research project proposal entitled "Investigations on flexoelectric properties of liquid crystals" was sanctioned in February 2008. Under this project, Academician A.G. Petrov, Director, Institute of Solid State Physics, Bulgarian Academy of Sciences, Sofia, Bulgaria visited the Centre during 24 November to 15 December 2010. [Investigators: Indian side - C. V. Yelamaggad, K.S. Krishnamurthy and S. Krishna Prasad; Bulgarian side - A. G. Petrov, Y. G. Marinov and H. P. Hinov]

- A three year Council of Scientific and Industrial Research – CSIR Project # 2162 on "Synthesis and liquid crystal behavior of chiral disc-rod oligomers" was sanctioned in

March 2008. The project was completed during the year. [Investigators: C. V. Yelamaggad, S. Krishna Prasad and D. S. Shankar Rao].

- A three year Department of Science & Technology – SERC (CVY1) Project on "Synthesis and characterization of Tris(N-salicylideneaniline) [TSAN]-based disc-shaped liquid crystals" was sanctioned in November 2007. The project was completed during the year. [Investigators: C.V. Yelamaggad, S. Krishna Prasad and D. S. Shankar Rao].

- A SERC Project entitled "Growth on technologically important crystals" was sanctioned during the year 2009-10. The first instalment has been received. The project is under progress. [Investigator: H.L. Bhat].

- Under the ongoing INSA-Hungarian Exchange Programme, Prof. Nandor Eber, Research Institute for Solid State Physics and Optics, Hungarian Academy of Sciences, Budapest, Hungary visited the Centre during 3-19 November 2010 and gave a colloquium.

- 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 during the year. [Investigators: Uma S. Hiremath and Project Mentor: Geetha G. Nair].

8. NATIONAL SCIENCE DAY

The Centre declared 28 February 2011 as Open Day for the public and the one week following that as National Science Week.

Karnataka Rajya Vijnana Parishat (KRVP) sponsored a visit of the College students selected for the Inter University Lecture Competition to CSMR on 4 March 2011. 26 students from different colleges of Karnataka accompanied by their instructors visited the Centre and had a day long program of talks, lab visits, and interaction with faculty and students of the Centre.

Faculty and students of CSMR responding to the rapid-fire questions from the KRVP students.

Students attentively listening to Mr. Prasad Bapat on high pressure effects in liquid crystal phase transitions.

Ms. Rashmi Prabhu demonstrating a novel chemical reaction.

Mr. Pramod Tadapatri sharing the excitement and challenges in the area of Soft Matter Research.

Mr. Prasad Bapat describing the diffraction pattern in a phase grating.

9. CLCR BECOMES CSMR

With effect from 1 September 2010, the name of the Centre was changed from 'Centre for Liquid Crystal Research' (CLCR) to 'Centre for Soft Matter Research' (CSMR). To commemorate this, a presentation meeting was held to explore the nature of the new research concerns of the Centre on 3 September 2010 with the following programme.

Programme

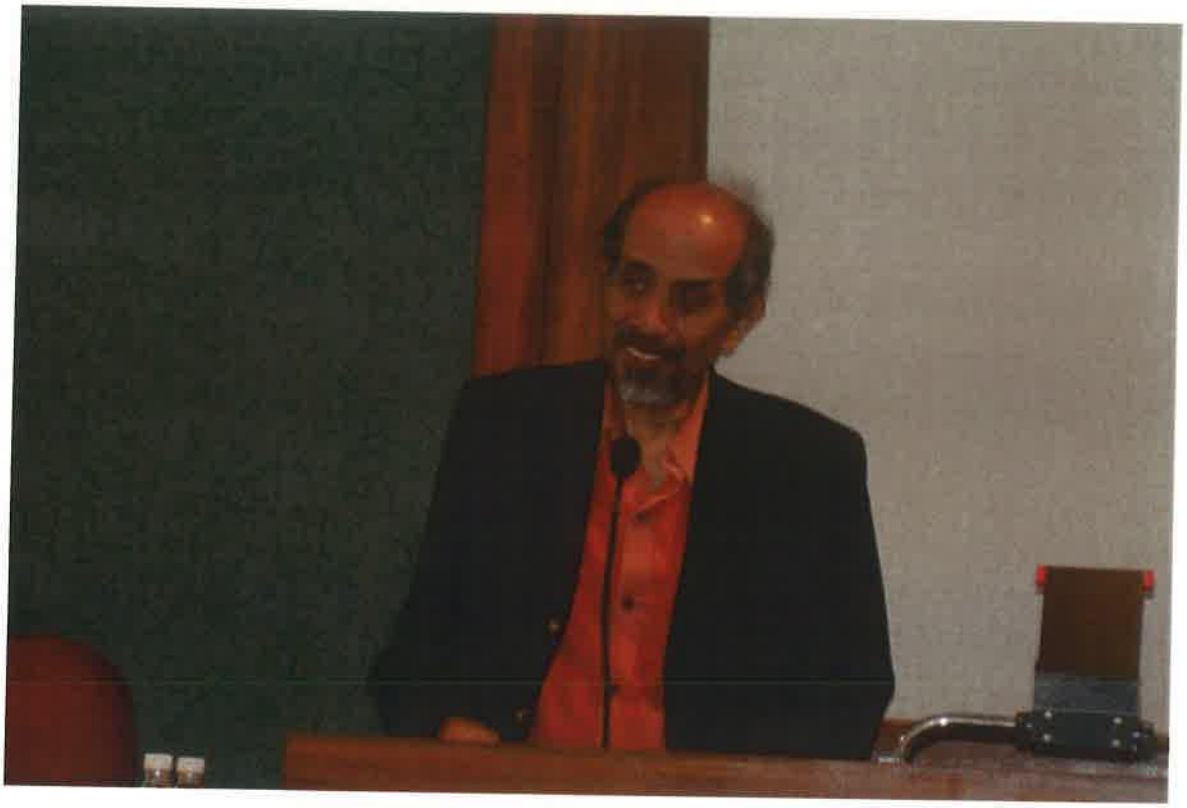
1. *Introductory Remarks*
   Prof. R.Narasimha, FRS, Chairman, Governing Council, CSMR

2. *Talk on Soft Matter*
   Prof. N.Kumar, Chairman, Research Advisory Board, CSMR

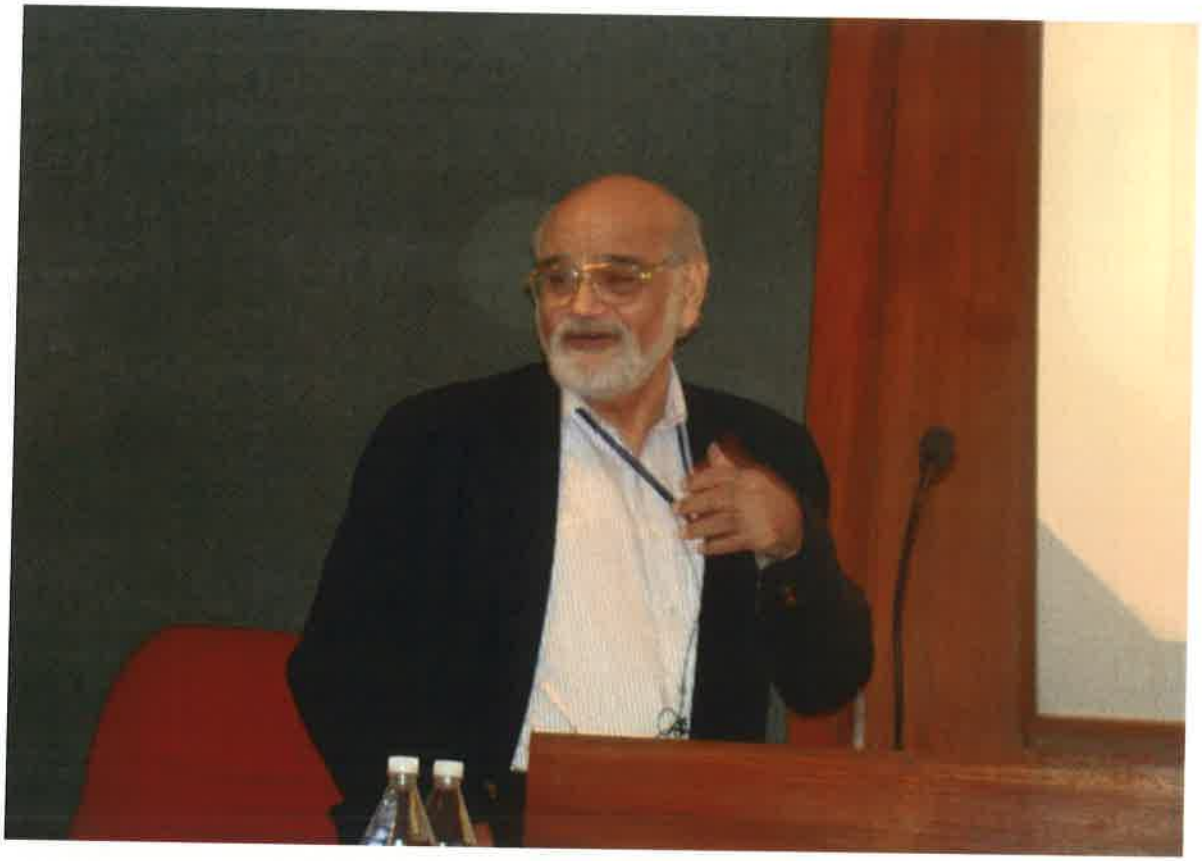
3. *Talk on Soft Matter Research and Future Direction at the Centre*
   Prof. K.A.Suresh, Scientist of Eminence, CSMR

Welcome by Prof. K.A. Suresh on the occasion of the renaming of the Centre.

Felicitation to Prof. R. Narasimha, Chairman of the Governing Council, CSMR.



Prof. R.Narasimha on the scope of Soft Matter Research.



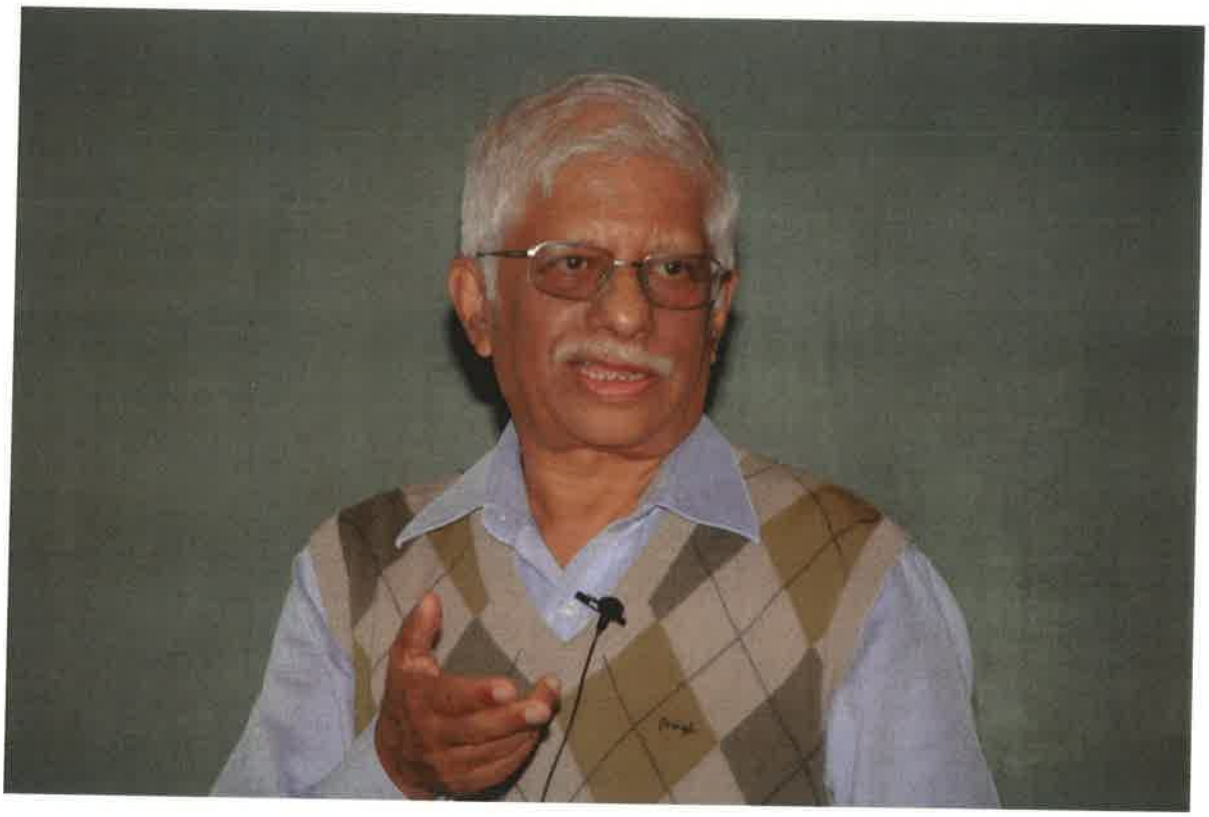
Prof. N.Kumar highlighting that Soft Matter is a natural evolution from Liquid Crystals.

Talk on the future directions in Soft Matter Research by Prof. K. A. Suresh.

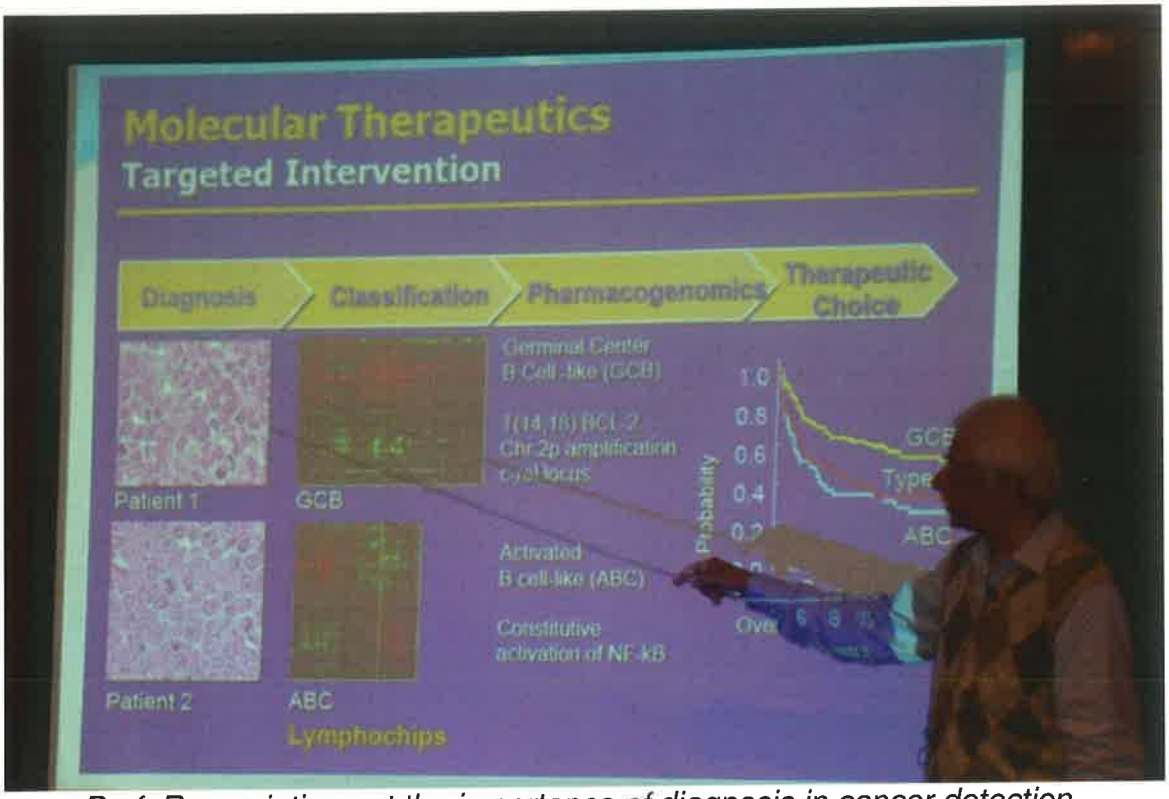
The Centre with its new name.

10. PROF. S. CHANDRASEKHAR MEMORIAL LECTURE

The 7th Prof. S. Chandrasekhar Memorial Lecture was delivered by Prof. M.R.S. Rao, President, Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore on 5 August 2010. The lecture was on "Genes, Genome and Cancer".

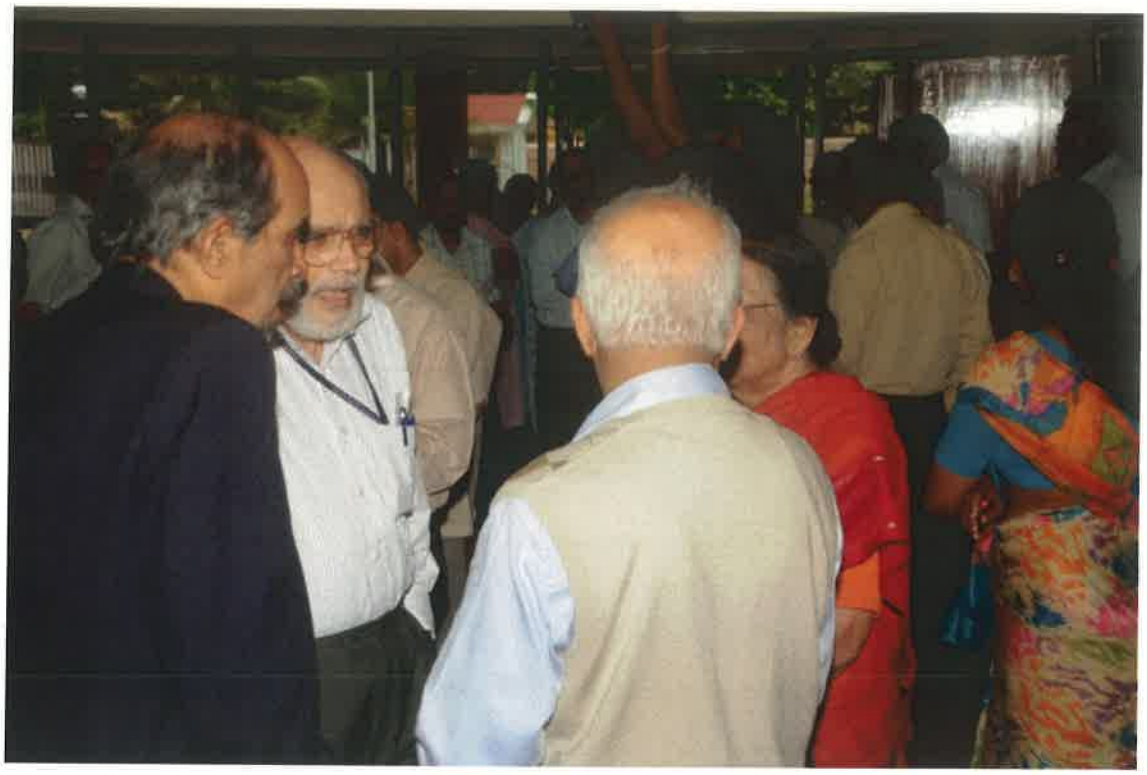


Prof. M.R.S.Rao delivering the 7th Prof. S. Chandrasekhar Memorial Lecture on "Genes,Genome and Cancer".



Prof. Rao pointing out the importance of diagnosis in cancer detection.

Audience listening to Prof. Rao's lecture with rapt attention.



Discussion on the general relevance of genes and genome.

11. STUDENTS' PROGRAMME

- Ms. V. Jayalakshmi, SRF was awarded Ph.D. degree by Mangalore University in November 2010 for her thesis entitled "Experimental investigations of electric field effects in liquid crystals". She is currently working as a post doctoral fellow at the Department of Chemistry, Queen's University, Canada.

- Mr. Pramoda Kumar, SRF was awarded Ph. D. degree by Mangalore University in August 2010 for his thesis entitled "Field driven reorientational and convective instabilities in nematic liquid crystals". He is currently working as a post doctoral fellow at the Max-Planck Institute for Dynamics und Self-Organisation, Gottingen, Germany.

- Mr. Sanjay K Varshney, visited the Tokyo Institute of Technology, Japan on an invitation from the Japan Society for the Promotion of Science (JSPS) as part of the RONPAKU (Dissertation Ph.D.) Programme during 29 May – 9 June and 12 October – 11 November 2010. He submitted his thesis entitled "Discotic liquid crystals as functional materials: synthesis and mesomorphism" and was awarded Ph.D. degree by Tokyo Institute of Technology, Japan in July 2010.

- During the year, two new students joined CSMR for the Ph.D. Programme.

12. AWARDS / HONORS

Prof. K. A. Suresh was invited to be a Member of the International Advisory Board of the 23rd International Liquid Crystal Conference held at Krakow, Poland during 11-16 July 2010.

13. POPULARIZATION OF SCIENCE :

PROF. K. A. SURESH

	Name of the Institute	Date	Title of talk
1	Deeksha KMWA PU College, Bangalore	26.11.2010	Imagine, innovate and integrate

DR. S.KRISHNA PRASAD

	Name of the Institute	Date	Title of talk
1.	Bapuji Institute of Engineering & Technology, Davanagere	28.02.2011	National Science Day Talk, Many facets of Soft Matter

2.	Karnataka Rajya Vijnana Parishat	19.02.2011 Raichur 06.02.2011 Yadgir 21.01.2011 Haveri 21.12.2010 Tumkur 21.12.2010 Madhurgiri 05.12.2010 Davanagere 06.12.2010 Chitradurga	Various aspects of Liquid Crystals and Nanotechnology
3.	Sri Venkateshwara College of Engineering, Yelahanka	29.04.2010	Liquid crystals, Laptops and Life

DR. C.V.YELAMAGGAD

	Name of the Institute	Date	Title of the talk
1.	**INSPIRE -2011** Organized by DST Govt. of India V. V. S. First Grade College for Woman, Basaveshwar Nagar, Bangalore.	09.03.2011	Fundamentals of Liquid Crystals and Their Applications
2.	Science Day 2011 Gandhi Grameen Gurukul, Residential School, Hosaritti, Haveri, Karnataka	03.03.2011	Liquid Crystals: A Unique State of Matter
3.	National Science Day (NSD) 2011 J. S. S. Academy of Technical Education, Srinivasapura, Bangalore.	28.02.2011	Recent Advances in Liquid Crystals
4.	B. M. S. Womens College Basavanagudi, Bugle Rock Road, Bangalore.	23.02.2011	Liquid crystals: A Unique State of Matter
5.	Scientists Interactive Program, Conducted by KRVP Jagadguru Panchacharya Mangalya Mandira, Gadag, Karnataka	18.02.2011	Liquid crystals: A Unique State of Matter
6.	L. V. D. College Raichur, Karnataka	05.02.2011	Chemistry of Liquid crystals

7.	First Educational Conference, Hatti organized by Raichur District's Mathematics and Science Teachers Association Swarna Bhavan, Hatti, Chinnada gani, Raichur district, Karnataka	04.02.2011	Chemistry : Within the Human Body and Around the Life
8.	Refresher Course for PU College organized by Vision Group on Science and Technology, Government of Karnataka H. K. Patil Krishi Vigyan Kendra, Hulkoti, Gadag, Karnataka.	16.12.2010	Liquid crystals: A Unique State of Matter
9.	Indian Academy Degree College Hennur cross, Hennur Main Road, Kalyan Nagar, Bangalore, Karnataka.	08.05.2010	Supramolecular Liquid Crystals

DR. P. VISWANATH

	Name of the Institute	Date	Title of talk
1.	M S Ramaiah Institute of Technology, Bangalore	26.11.2010	Combating and Counterfeiting with Lasers

PROF. K. S. KRISHNAMURTHY

	Name of the Institute	Date	Title of talk
1.	"Karnataka Vijnana Vidya Jagruthi : Student - Scientist interaction programme" organized by Karnataka Rajya Vijnana Parishat Govt. First Grade College, Chikkaballapur	13.12.2010	Liquid Crystals and Modulation of Light

PROF. G. S. RANGANATH

	Name of the Institute	Date	Title of talk
1.	Bangalore Planetarium	28.04. 2010	Vision in Animals
2.	Bangalore Planetarium	25.06.2010	Geometrical Optics
3.	Indian Academy Degree College, Bangalore-560043	02.07.2010	Physics in Natural Settings
4	R.V. P.U. College, Bangalore	21.09.2010	In the Wonder Land of Light
5	Vijaya Teachers College Bangalore	25.20.2010	Some Interesting Experiments in Physics
6	Ambedkar's Institute of Technology, Bangalore	28.02.2011	Young Scientists
7	Inspire programme of DST, Vidyavardhaka College, Bangalore	08.03.2011	Photons

PROF. H. L. BHAT

	Name of the Institute	Date	Title of talk
1.	Kendriya Vidyalaya, Jalahalli, Bangalore	13.05.2010	Discovery of Laser: A Historical perspective
2.	Siddaganga Institute Technology, Tumkur	26.06.2010	Instrumentation for Crystal Growth
3.	Jyothi High School, Hoskote	07.08.2010	Optics through Laser
4.	MES PU College, Vidyaranyapura, Bangalore	17.09.2010	Fifty years of Lasers
5.	Jyothi High School, Hoskote	08.11.2010	Lasers and Optics
6.	KRVP programme, Davangere	05.12.2010	Lasers and their Applications

7.	KRVP programme, T.R.S.Town Hall, Chitradurga	06.12.2010	Fifty years of Lasers
8.	Govt. Science college, Chitradurga	06.12.2010	Lasers : past, present and future.
9.	Refresher course for college teachers, Central College, Bangalore	23.12.2010	Laser as a teaching aid
10.	XXV Refresher Course in Experimental Physics, Indian Academy of Sciences, Bangalore	29.12.2010	Discovery of Laser: A Historical perspective
11.	Kendriya Vidyalaya, Jalahalli, Bangalore	01.01.2011	Photons to Laser: Sixty years of Scientific Endeavour
12.	Refresher Course for Secondary school teachers, Siddaganga Education Society, Tumkur	08.01.2011	Electromagnetic Radiation and Laser
13.	INSPIRE Programme, I Square IT, PUNE	13.01.2011	Lasers and their Applications
14.	KRVP programme, Puttur, Dakshina Kannada Dist.	21.12.2010	Einstien to Theodre Maiman: the Laser connection
15.	KRVP programme, Shravanabalagola, Hasan Dist.	09.02.2011	Photons to Laser: Sixty years of Scientific Endeavour
16.	KRVP programme, A.I.T.College, Chikkamagaluru	11.02.2011	Photons to Laser: Sixty years of Scientific Endeavour
17.	Talent Development Centre, IISc Challakere campus	27.02.2011	Photoelectric Effect
18.	Talent Development Centre, IISc Challakere campus	28.02.2011	Lasers : past, present and future.

14. VISITS ABROAD

- Prof. K. A. Suresh attended the 23rd International Liquid Crystal Conference held in Krakow, Poland during 11–16 July 2010 and gave an oral presentation entitled "Nanoscale electrical conductivity of monolayer films of discotic liquid crystalline molecules". During

this visit, he also attended the meeting of the Executive Board of the International Liquid Crystal Society as a Member.

- Prof. K. A. Suresh visited the Institute of Solid State Physics, Bulgarian Academy of Sciences, Sofia, during 17–24 July 2010 as a part of the ongoing Indo-Bulgarian collaboration. This visit included delivering a colloquium, interaction with researchers, and discussion about future plans on the collaboration.

- Prof. H. L. Bhat attended the International Conference on Superconductivity and Magnetism (ICSM-2010) held at Antalya, Turkey during 25–30 April 2010 and gave a oral presentation on " Low temperature Glassy phase in $Gd_{0.5}Sr_{0.5}MnO_3$".

- Dr. S. Angappane attended the ICPC Nanonet Project 2nd Annual Workshop held at Unisplendour International Centre, Beijing, China on 14–15 June 2010 and made a presentation on " Innovations in Indian Nano Research-2009".

15. SEMINARS / TALKS GIVEN AT OTHER INSTITUTES

- Prof. K. A. Suresh attended the 17th National Conference on Liquid Crystals held at Veer Narmad South Gujarat University, Surat during 15–17 November 2010 and gave an invited talk on "Conductivity of monolayer films of mesogenic oligomer".

- Dr. S. Krishna Prasad attended 17th National Conference on Liquid Crystals held at Surat, during November 15–17, 2010 and gave an invited talk on "Enhancement of anisotropic conductivity, elastic and dielectric constants in a liquid crystal-gold nanorod system", and also chaired a session.

- Prof. K. S. Krishnamurthy attended the 17th National Conference on Liquid Crystals held at Surat, during 15–17 November 2010 and gave an invited talk on "Multiple electroconvection scenarios in bent-core nematic liquid crystals".

- Dr. Veena Prasad attended National Seminar on Modern Methods in Organic Chemistry held at Christ University, Bangalore during 18–19 February 2011 and gave an invited talk on "Photosensitive phasmid-like liquid crystalline materials with unusual mesomorphic properties".

- Dr. C. V. Yelamaggad attended a One day national symposium on "Frontiers in Chemical' Sciences (FCS 2011)" held at the Department of Chemistry and Chemical, Technology Vidyasagar University, Midnapore, West Bengal on 13 March 2011 and gave an invited talk on "Supramolecular Liquid Crystals: Facile Synthesis and Characterization of Novel Self-Complementing Systems Derived From Amino Acids"

- Prof. H. L. Bhat attended the National Conference on Laser and its Applications held at National College Basavangudi, Bangalore on 4 October 2010 and delivered the inaugural talk on "Laser: A Historical Perspective".

- Prof. H. L. Bhat attended the XVI National Seminar on Ferroelectrics and Dielectrics held at Guru Ghasidas University , Bilaspur during 2–4 December 2010 and delivered invited talk on "Polarization switching in congruent, near stoichiometric and Zn doped near stoichiometric LiNbO3 at high temperatures ".

- Dr. Veena Prasad attended a workshop sponsored by Karnataka Science & Technology Academy held at Mangalore University, Mangalore during 8-10 October 2010 and gave invited talks on "Introduction to liquid crystals" and "Photo-chromic bent-core liquid crystals".

- Prof. H. L. Bhat attended the XV National Siminar on Crystal Growth held at SSN College of Engineering and Technology, Tirunelveli during 23–25 February 2011 and delivered the invited talk on " Instrumentation in Crystal Growth Research".

- Prof. K.A. Suresh was invited to deliver two lectures at the Workshop on "Recent Trends in Physics", sponsored by the Joint Science Education Programme of the three Academies of India at the Amrita School of Arts & Sciences, Amrita Viswa Vidyapeetham, Kollam, Kerala, during 23-25 March 2011.

- Prof. K.A. Suresh visited Guru Nanak Dev University, Amritsar during 21-23 December, 2010 and delivered a talk on "Liquid Crystals - Structure and properties" on 23.12.2010.

- Dr. S. Krishna Prasad visited LVD College, Raichur and gave a talk entitled "Many facets of Soft Matter" on 19 February 2011.

- Dr. Veena Prasad visited Mangalore University, Mangalore during 25-27 October 2010 and gave four invited guest lectures of one hour duration each on "Chemistry and Physics of Liquid Crystals" to M.Sc. Industrial Chemistry students.

- Dr. C. V. Yelamaggad visited Gopalan College of Engineering and Management, Hoodi Village, Whitefield, Bangalore, Karnataka on 20 April 2011 and gave a lecture on " Liquid Crystals: A Unique State of Matter. Applications and Fundamental Aspects" to B.E. students and faculty members.

- Dr. C. V. Yelamaggad visited Department of Chemistry and Chemical Technology, Vidyasagar University, Midnapore, West Bengal on 12 March 2011 and gave a lecture on "Liquid Crystals: A Unique State of Matter : Fundamentals & Applications" to M. Sc. and Ph.D. students.

- Prof. K. S. Krishnamurthy visited Mysore University as an invited examiner for M. Sc. (Physics) examination of Mysore University, held in June–July 2010, framed a question paper on "Liquid Crystals" (a special subject).

- Prof. G. S. Ranganath visited Bangalore Planetarium - REAP Programme and gave four talks on " Quantum Mechanics" on 24 & 31 July and 7 & 14 August 2010.

- Prof. G.S.Ranganath participated in the Refresher Course in Bangalore University and gave two Lectures on "Electromagnitism" on 4 January 2011.

- Prof. G.S.Ranganath visited St. Joseph's College, Bangalore under their Postgraduate Programme and gave talk on "Electromagnetism" - 2 Lectures on 4 January 2011.

16. LECTURES BY VISITORS

- Academician A.G. Petrov, Director, Institute of Solid State Physics, Bulgarian Academy of Sciences, Sofia, Bulgaria visited the Centre from 24 November to 15 December 2010 under the Indo-Bulgarian Inter-Governmental Programme of Co-operation in Science & Technology. He gave a colloquium on "Low frequency spectra of dielectric and

flexoelectric oscillations in PDLC" on 9 December 2010. He also gave a talk on "Prof. V. K. Freederickz and his effect" on 10 December 2010.

Group photo on the occasion of the Colloquium of Prof. N. Eber, Research Institute for Solid State Physics and Optics, Budapest.

- Prof. Stefan Heun, Instituto Nanoscienze-CNR and Scuola Normale Superiore, Pisa, Italy visited the Centre on 30 November 2010 and gave a colloquium on "Coexistence of vapor-liquid-solid and vapor-solid-solid growth modes in Pd-assisted InAs nanowires".

- Prof. Jagdish K. Vij, Trinity College, University of Dublin, Ireland visited the Centre on 25 November 2010 and gave a colloquium on "Continuous transformations between synclinic and anticlinic phases".

- Prof. Nandor Eber, Research Institute for Solid State Physics and Optics, Hungarian Academy of Sciences, Budapest, Hungary visited the Centre under the INSA-Hungarian Bilateral Programme, during 3–19 November 2010 and gave a colloquium entitled

"Electroconvection in nematic mixtures of a bent-core and a calamitic molecule" on 11 November 2010.

- Prof. Renugopalakrishnan, Northeastern University & Harvard Children's Hospital, Boston, USA visited the Centre on 1 October 2010 and gave a colloquium on "Intelligent smart proteins for hyper dense memory: DVD, USB, iPhones".

- Dr. Zsombor Feldoto, Biolin Scientific, Sweden visited the Centre on 26 October 2010 and gave a colloquium on "Quartz crystal microbalance".

17. SEMINARS GIVEN AT THE CENTRE

- Mr. M. Vijayakumar gave a seminar on "Influence of confined geometry on anisotropic soft matter" on 15 September 2010.

- Ms. Hashambi K. Dambal gave a seminar on "Molecular design, synthesis and characterization of some novel thermotropic liquid crystals" on 29 September 2010.

- Ms. Shilpa Harish .T. gave a seminar on "Studies on organic-inorganic hybrid thin films at interfaces" on 13 October 2010.

- Ms. Gayathri .K. gave a seminar on "A study on structure-property relations of some novel thermotropic liquid crystalline materials" on 22 October 2010.

- Ms. R. Rajalakshmi gave a seminar on "Synthesis and characterization of dilute magnetic semiconductor thin films" on 27 October 2010.

18. LIST OF SCIENTISTS AND RESEARCHERS

	Name	Designation
1.	Prof. K. A. Suresh	Director (till 31.07.2010) & Scientist of Eminence (since 1.8.2010)
2.	Dr. S. Krishna Prasad	Scientist F (since 01-11-2010)
3.	Dr. Geetha G. Nair	Scientist D (since 01-11-2010)

4.	Dr. D. S.Shankar Rao	Scientist D (since 01-11-2010)
5.	Dr. Veena Prasad	Scientist D (since 01-11-2010)
6.	Dr. C. V. Yelamaggad	Scientist D (since 01-11-2010)
7.	Dr. P. Viswanath	Scientist C
8.	Dr. S. Angappane	Scientist C
9.	Dr. Neena Susan John	Scientist C (Joined on 04-10-2010)
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 (since 24-01-2011)
14.	Ms. V. Jayalakshmi	Senior Research Fellow*
15.	Mr. Pramoda Kumar	Senior Research Fellow*
16.	Ms. S. Sridevi	Senior Research Fellow
17.	Mr. Pramod Tadapatri	Senior Research Fellow
18.	Mr. Prasad N.Bapat	Senior Research Fellow
19.	Ms. Rashmi Prabhu	Junior Research Fellow
20.	Ms. N. G. Nagaveni	Junior Research Fellow
21.	Ms. R. Bhargavi	Junior Research Fellow
22.	Mr. K. R. Vinaya Kumar	Junior Research Fellow
23.	Ms. T. Shilpa Harish	Junior Research Fellow
24.	Mr. M. Vijaykumar	Junior Research Fellow
25.	Ms. R. Rajalakshmi	Junior Research Fellow
26.	Ms. Hashambi K.Dambal	Junior Research Fellow
27.	Ms. K. Gayathri	Junior Research Fellow
28.	Mr. Nagaiah Kambhala	Junior Research Fellow

29.	Ms. H. N. Gayathri	Junior Research Fellow
30.	Ms. Halley M. Menezes	Project Assistant[#]

** Since graduated and left* *[#] Left on project completion*

19. ADMINISTRATIVE STAFF

Name	Designation
Shri Subhod M. Gulvady	Administrative Officer
Shri K.R.Shankar	Accounts Officer
Shri L. Chandra Sekhar	Maintenance Engineer
Smt P.Nethravathi	Office Superintendent
Dr. Sanjay K. Varshney	Technical Assistant
Smt. Sandhya D. Hombal	Technical Assistant
Shri M. Jayaram	U.D.C.
Shri Naveen C. Mathad	Library Assistant
Shri Govindappa	Consultant in Administration

20. PUBLICATIONS DURING 2010-2011

Technical Reports / Monographs

1. **Chapter 11**. titled "Growth and Characterization of Antimony based narrow band gap III-V semiconductor crystals" by V.K.Dixit and H.L.Bhat in the book '**Springer Hand Book of Crystal Growth**'

Publications

1. Critical behavior of three organosiloxane de Vries-type liquid crystals observed via the dielectric response, S Krishna Prasad, D S Shankar Rao, S Sridevi, Jawad Naciri and B R Ratna, ***J. Phys.: Condens. Matter 23, 105902 (2011).*** Selected for IoP Collections, in which articles are chosen by journal editors for their novelty, significance and potential impact on future research. Also highlighted as a News item, Contradictions coexist in smectic liquid crystals, http://iopscience.iop.org/0953-8984/labtalk-article/45336

2. Anomalously large bend elastic constant and faster electro-optic response in anisotropic gels formed by a dipeptide, R. Bhargavi, Geetha G. Nair, S. Krishna Prasad, Rashmi Prabhu and C. V. Yelamaggad, ***J. Appl. Phys. 109, 083537 (2011)***

3. Novel green light emitting nondiscoid liquid crystalline zinc(II) Schiff- base complexes, C. R. Bhattacharjee, Gobinda Das, P. Mondal, S. Krishna Prasad and D.S. Shankar Rao, ***Eur.J.Inorg.Chem., 1418 (2011).***

4. Novel photoluminescent lanthanidomesogens forming bilayer smectic phase derived from blue light emitting liquid crystalline, one ring O-donor Schiff-base ligands, C. R. Bhattacharjee, Gobinda Das, P. Goswami, P. Mondal, S. Krishna Prasad, D.S. Shankar Rao, ***Polyhedron 30, 1040 (2011)***.

5. Occurrence of unusually wide thermal range enantiotropic twist grain boundary TGBC* phases in unsymmetrical cholesterol and oxadiazole based liquid crystalline dimers, K. C. Majumdar, P. K. Shyam, D. S. Shankar Rao and S. Krishna Prasad, ***J. Mater. Chem., 21, 556 (2011).***

6. Wide thermal range frustrated liquid crystal phase in chiral dimers, Uma S. Hiremath, Girija M. Sonar, D. S. Shankar Rao and C. V. Yelamaggad, ***J. Mater. Chem., 21, 4064 (2011)***.

7. Room-temperature discotic cholesteric and nematic phases: Influence of 3,7-dimethyl-octane peripheral chain on the molecular self-assembly of radial polyalkynylbenzene, S.K. Varshney, Veena Prasad and H. Takezoe, ***Liq. Cryst., 38, 53 (2011)***.

8. Benzylidenehydrazine based room temperature columnar liquid crystals, G. Shanker, M. Prehm, C. V. Yelamaggad and C. Tschierske, ***J. Mater. Chem., 21, 5307 (2011)***.

9. Study of the Low Temperature Glassy Phase in $Gd_{0.5}Sr_{0.5}MnO_3$ Single Crystals, A.A.Wagh, P.S.A.Kumar, H.L. Bhat, et al., ***J. Supercond. and Novel Magnetism, 24, 665 (2011) .***

10. Observation of Spin-Glass Behavior in $La_{0.85}Sr_{0.15}CoO_3$ Single Crystals, K.Manna, D.Samal, S. Elizabeth, H.L. Bhat and P.S.A. Kumar, ***J. Supercond. and Novel Magnetism, 24, 833 (2011).***

11. Effect of substitution of Y on the structural, magnetic, and thermal properties of hexagonal DyMnO3 single crystals, H.S.Nair, C.M.N.Kumar, H.L. Bhat, et al. ***Phys. Rev. B, 83, 104424 (2011)***.

12. Electron paramagnetic resonance studies on Mn doped GaSb, K.Ganesan, S.S.Rao, S.V.Bhat, H.L.Bhat et al., ***J. Appl. Phys, 109, 033903 (2011)***.

13. Raman scattering study of phase biaxiality in a thermotropic bent-core nematic liquid crystal, Min Sang Park, Beom-Jin Yoon, Jung Ok Park, Veena Prasad, Satyendra Kumar and Mohan Srinivasarao, ***Phys. Rev. Lett., 105, 027801 (2010)***.

14. Stress-strain relation in the collapse of Langmuir monolayer of a dimer of disk shaped moiety, Bharat Kumar, K.A.Suresh, Satyam K.Gupta and Sandeep Kumar, ***The Jour. of Chem. Phys.***, **133**, 044701 (2010)

15. Confinement-driven weakening of the rotator phase transitions in an alkane through a possible tricritical point, M. Vijay Kumar, S. Krishna Prasad and D.S. Shankar Rao, ***Langmuir, 26, 18362 (2010).***

16. Enhancement of anisotropic conductivity, elastic and dielectric constants in a liquid crystal-gold nanorod system, S. Sridevi, S. Krishna Prasad, Geetha G. Nair, Virginia D'Britto and B.L.V. Prasad, ***Appl. Phys. Lett., 97, 151913 (2010)***. *Selected by AIP for publication in the Virtual Journal of Nanoscale science and Technology, October 18, 2010 issue [Vol. 22 Issue 17]*

17. Cholesterol based unsymmetrical Schiff's base dimer terminated with 4-alkoxy-5-phenylthiophene unit: Synthesis and characterization, K. C. Majumdar, Tapas Ghosh, Santanu Chakravorty, Nilashis Pal, D. S. Shankar Rao and S. Krishna Prasad, ***Liq. Cryst., 37, 1539 (2010)***

18. Conoscopic evidence of the UV light-induced flexoelectric effect in homeotropic layers of nematic liquid crystal doped with azobenzene derivatives, Y. G. Marinov, G. B. Hadjichristov, A. G. Petrov, S. Sridevi, U. S. Hiremath, C. V. Yelamaggad and S. K. Prasad, ***J. Phys.: Conf. Ser. 253, 012060 (2010).***

19. High-pressure dielectric investigations of nanocolloidal aerosil-nematic liquid crystal composites, Prasad N. Bapat, D. S. Shankar Rao, S. Krishna Prasad, and C. V. Yelamaggad, ***J. Phys. Chem. B, 114, 12825 (2010)***.

20. The first examples of supramolecular discotic C3h tris(N-salicylideneamine)s featuring inter- and intra-molecular H-bonding: Synthesis and characterization, C. V. Yelamaggad, Rashmi Prabhu, D. S. Shankar Rao and S. Krishna Prasad, ***Tetrahedron Lett. 51, 4471 (2010)***

21. Diminution of the ordering in plastic and liquid crystalline phases by confinement, S. Krishna Prasad, S. Sridevi and D. S. Shankar Rao, ***J. Phys. Chem. B, 114, 7474 (2010)***.

22. Light induced generation of stable blue phase in photoresponsive diphenylbutadiene based mesogen, R. K. Vijayaraghavan, Shibu Abraham, D. S. Shankara Rao, S. Krishna Prasad and Suresh Das, ***Chem. Commun., 46, 2796 (2010).***

23. Role of hydroxyl group on the mesomorphism of alkyl glycosides: synthesis and thermal behavior of alkyl 6-deoxy--d-glucopyranosides, M.K. Singh, N. Jayaraman,, D.S. Shankar Rao, S. Krishna Prasad, ***Chem. Phys. Lipids, 163, 580 (2010).***

24. Synthesis and liquid-crystalline properties of β-bromopentakis(alkoxy) triphenylene: reactivity of $VOCl_3$, $MoCl_5$, and $FeCl_3$ as oxidants, S.K.Varshney, H.Nagayama, D.S Shankar Rao and H. Takezoe, ***Mol. Cryst. Liq. Cryst., 528, 36 (2010)***.

25. Photosensitive phasmid – like liquid crystalline materials with unusual mesomorphic behavior, N.G. Nagaveni, Meenal Gupta, Arun Roy and Veena Prasad, ***J. Mater. Chem., 20, 9089 (2010)***.

26. Non-symmetrical discotic liquid crystalline dimers: molecular design, synthesis and mesomorphic properties, S.K. Varshney, H. Monobe, Y. Shimizu, H. Takezoe and Veena Prasad, ***Liq. Cryst., 37, 607 (2010)***.

27. Multifunctional spin-carrying anthraquinone derivatives, H. Akutsu, J. Yamada, M. Satoh, Uma S. Hiremath, C. V. Yelamaggad, and S. Nakatsuji, ***Chem. Lett., 39, 671 (2010)***.

28. Thermodynamic and electrical characteristics of the twisted grain boundary phases of 4-n-dodecyloxy-4'-(cholesteryloxycarbonyl-1-butyloxy) chalcone, V. S. Pandeya, R. Dhar, A. Kr. Singha, A. S. Achalkumar and C.V. Yelamaggad, ***Phase Transitions, 83, 1049 (2010)***.

29. Effect of polymer coating on the magnetic properties of oxygen-stabilized nickel nanoparticles, Vidyadhar Singh, V. Srinivas, M. Ranot, S. Angappane, and Je-Geun Park, ***Phys. Rev. B, 82, 054417 (2010)***.

30. Multiple electroconvection scenarios in a bent-core nematic liquid crystal, Pramod Tadapatri, K. S. Krishnamurthy, and W. Weissflog, ***Phys. Rev. E, 82, 031706 (2010)***.

31. Disorder-driven electronic localization and phase separation in superconducting $Fe_{1+y}Te_{0.5}Se_{0.5}$ single crystals, S.Rossler, D.Cherian, S.Harikrishnan, H.L.Bhat et al., ***Phys. Rev. B, 82, 144523 (2010)***.

32. Negative differential resistance in $Gd_{0.5}Sr_{0.5}MnO_3$: A consequence of Joule heating, A.A.Wagh, P.S.A.Kumar, H.L.Bhat et al., ***J. Appl. Phys., 108, 063703 (2010)***.

33. Optical absorption and photoluminescence studies on heavily doped (Ga,Mn)Sb crystals, K.Ganesan, N.B.Pendyala, K.S.R.K.Rao, H.L. Bhat et al., ***J. Semiconductor Sci. & Tech., 25, 105003 (2010)***.

34. Memory effect in $Dy_{0.5}Sr_{0.5}MnO_3$ single crystals, S.Harikrishnan, S.Rossler, C.M.N.Kumar, Y.Xiao, H.L. Bhat et al., ***J. Phys: Cond. Matt., 22, 346002 (2010)***.

35. Polarization switching in near-stoichiometric Zn:$LiNbO_3$ at high temperatures, J.N.B.Reddy, H.L. Bhat, S. Elizabeth, ***Solid State Commn., 150, 1258 (2010)***.

36. Atomically resolved scanning tunneling microscopy on perovskite manganite single crystals, S. Roessler, B. Padmanabhan, S. Elizabeth, H.L. Bhat et al., ***Appl. Phys. Lett., 96, 02512 (2010)***.

In press

37. Twist disclination loops in a bent-core nematic liquid crystal, K. S. Krishnamurthy, Pramod Tadapatri and W. Weissflog, ***Soft Matter (in press)***

38. Lamellar columnar mesomorphism in a series of oxovanadium(IV) complexes derived from N, N/-di-(4-n-alkoxysalicylidene)diaminobenzene, C. R. Bhattacharjee, Gobinda Das, P. Mondal, S. Krishna Prasad, D. S. Shankar Rao, ***Inorganic Chemistry Communications (in press)***.

39. Plastic columnar mesomorphism in half-disc-shaped oxovanadium (IV) Schiff base complexes, C.R. Bhattacharjee, Gobinda Das, Paritosh Mondal, S. Krishna Prasad, D. S. Shankar Rao, ***Liq. Cryst. (in press)***.

40. New photoactive guest-host nematics showing photo-flexoelectricity, A.G. Petrov, Y. G. Marinov, G.B. Hadjichristov, S. Sridevi, Uma S. Hiremath, C.V. Yelamaggad, and S. Krishna Prasad, ***Mol. Cryst. Liq. Cryst. (in Press)***

41. 2-phenylbenzoxazole-containing calamitic liquid crystals: synthesis and characterisation, K.C. Majumdar, T. Ghosh, D.S. Shankar Rao and S. Krishna Prasad, ***Liq. Cryst. (in press).***

Papers & Posters presented at the Conferences

1) *Spreading and retraction dynamics of dye doped liquid crystalline domains at the air-water interface,* P.Viswanath, K.A.Suresh and Bharat Kumar, Oral presentation at the 17thNational Conference on Liquid Crystals held at Surat, during 15-17 November 2010.

2) *Diminution of the ordering in plastic and liquid crystalline phases by confinement in alumina nanochannels,* D.S.Shankar Rao, S.Krishna Prasad and S.Sridevi, Oral presentation at the 17thNational Conference on Liquid Crystals held at Surat, during 15-17 November 2010.

3) *Achiral and chiral nonsymmetric liquid crystal dimers derived from cyanobiphenyl and salicylaldimine cores: Synthesis & mesomorphism,* C.V.Yelamaggad, V.Padmini, Geetha G.Nair, D.S.Shankar Rao and S.Krishna Prasad, Oral presentation at the 17thNational Conference on Liquid Crystals held at Surat, during 15-17 November 2010.

4) *The first examples of supramolecular discotic C3H tris(N-Salicylideneamine)s featuring inter- and intra-molecular H-bonding: Synthesis and characterization,* Rashmi Prabhu, D.S.Shankar Rao, S.Krishna Prasad and C.V.Yelamaggad, Oral presentation at the 17thNational Conference on Liquid Crystals held at Surat, during 15-17 November 2010.

5) *Nonsymmetric liquid crystal dimers comprising banana-shaped and rod-like anisometric segments: synthesis and mesomorphism,* Hashambi K. Dambal, Uma S. Hiremath, C.V.Yelamaggad, Geetha G.Nair, D.S.Shankar Rao and S.Krishna Prasad, Poster presentation at the 17thNational Conference on Liquid Crystals held at Surat, during 15-17 November 2010.

6) *High pressure dielectric investigations of nanocolloidal aerosil-nematic liquid crystal composites,* Prasad N. Bapat, D.S.Shankar Rao, S.Krishna Prasad and C.V.Yelamaggad, Poster presentation at the 17thNational Conference on Liquid

Crystals held at Surat, during 15-17 November 2010.

7) *Azo-dye doped nematic liquid crystals as photosensitive flexoelectric guest-host systems,* S.Sridevi, U.S. Hiremath, C.V.Yelamaggad, S.K.Prasad, Y.G.Marinov, G.B.Hadjichristov and A.G.Petrov, Poster presentation at the 17thNational Conference on Liquid Crystals held at Surat, during 15-17 November 2010.

8) *Confinement-driven weakening of the rotator phase transitions in a long chain alkane,* M.Vijay Kumar, S.Krishna Prasad and D.S.Shankar Rao, Poster presentation at the 17thNational Conference on Liquid Crystals held at Surat, during 15-17 November 2010.

9) *Anomalously large bend elastic constant and faster electro-optic response in anisotropic gels,* R.Bhargavi, Geetha G.Nair, S.Krishna Prasad, Rashmi Prabhu and C.V.Yelamaggad, Poster presentation at the 17thNational Conference on Liquid Crystals held at Surat, during 15-17 November 2010.

10) *Dilations rheology of Langmuir monolayer of a fatty acid by oscillatory barrier method,* Vinaya Kumar and K.A.Suresh, Poster presentation at the 17thNational Conference on Liquid Crystals held at Surat, during 15-17 November 2010.

11) *Dislocations and metastable chevrons in the electroconvective inplane normal roll state of a bent core nematic liquid crystal,* Pramod Tadapatri and K.S.Krishnamurthy, Poster presentation at the 17thNational Conference on Liquid Crystals held at Surat, during 15-17 November 2010.

12) *Growth of zinc oxide pnano weeds" and " Exchange bias effects in F_{e3O4}/γ-F_{e2O3} core/shell nanoparticles,* Dr. S. Angappane attended the JNC-Purdue workshop on "Basics of Nanomaterials and Applications in Energy Conversion, Transport and Storage" held at JNCASR, Bangalore, during 20–21 August 2010 and made two poster presentations.

CENTRE FOR SOFT MATTER RESEARCH

(Formerly Centre for Liquid Crystal Research)

BENGALURU

STATEMENT OF ACCOUNTS FOR THE YEAR 2010 – 2011 AND THE BALANCE SHEET AS ON 31.03.2011

B.R.V. Goud & Co.
Chartered Accountants

Date: 06.07.2011

AUDITORS REPORT TO THE MEMBERS OF CENTRE FOR SOFT MATTER RESEARCH (Formerly know as Centre for Liquid Crystal Research)

1. We have audited the attached Balance Sheet of **CENTRE FOR SOFT MATTER RESEARCH, BANGALORE – 560 013**, as at 31st March 2011 and the Income and Expenditure Account for the year ended on that date, annexed thereto. These Financial statements are the responsibility of the Management. Our responsibility is to express an opinion on these Financial Statements based on our Audit.

   We have 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 by management, as well as evaluating the overall Financial Statement presentation. We believe that our audit provides a reasonable basis for our opinion.

2. 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.

3. In our opinion, proper Books of Accounts as required by law have been kept by the CENTRE so far as appears from our examination of such books.

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

5) In our opinion and to the best of our information and according to the explanations given to us, the said accounts read with the schedules thereon give a true and fair view:

   a) In the case of the Balance Sheet, of the state of affairs of the CENTRE as at 31st March 2011.

   AND

   b) In the case of Income and Expenditure Account, of the Excess of Expenditure over Income for the year ended on that date.

for B.R.V. GOUD & CO.,
Chartered Accountants

(A.B.SHIVA SUBRAMANYAM)
PARTNER

1st Floor, 'Sai Complex', #1/1
Museum Road, Bangalore 560 001
Phone: 080 - 25596468

TelePax: 080 - 25586042
E-mail: info@brvg.co.in
Website: www.brvg.co.in

CENTRE FOR SOFT MATTER RESEARCH (Formerly known as Centre for Liquid Crystal Research)
JALAHALLI, BANGALORE - 560 013

BALANCE SHEET AS AT 31ST MARCH, 2011

(Amount in Rupees)

I. CORPUS / CAPITAL FUND AND LIABILITIES	SCH	As at 31.03.2011	As at 31.03.2010
CORPUS / CAPITAL FUND	1	110,460,166	112,497,673
RESERVES AND SURPLUS	2	-	-
EARMARKED PROJECTS FUNDS	3	5,592,909	5,949,337
SECURED LOANS AND BORROWINGS	4		-
UNSECURED LOANS AND BORROWINGS	5	-	-
DEFERRED CREDIT LIABILITIES	6	-	-
CURRENT LIABILITIES AND PROVISIONS	7	337,457	553,566
TOTAL		**116,390,532**	119,000,576
I I APPLICATION OF FUNDS/ASSETS			
FIXED ASSETS	8	83,388,226	74,050,359
INVESTMENTS - FROM EARMARKED/ENDOWMENT FUNDS	9	-	-
INVESTMENTS - OTHERS	10	-	-
CURRENT ASSETS, LOANS, ADVANCES ETC.,	11	33,002,306	44,950,217
TOTAL		**116,390,532**	119,000,576
NOTES ON ACCOUNTS	24		

As per our report of even date,
for B.R.V.Goud & Co.,
Chartered Accountants,

(Dr.PRAVEER ASTHANA)
DIRECTOR

(K.R.SHANKAR)
ACCOUNTS OFFICER

(A.B.SHIVA SUBRAMANYAM)
PARTNER

PLACE :BANGALORE
DATE 06.07.2011

CENTRE FOR SOFT MATTER RESEARCH (Formerly known as Centre for Liquid Crystal Research)
JALAHALLI, BANGALORE - 560 013

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31ST MARCH, 2011

(Amount in Rupees)

A - INCOME	SCH	2010-11	2009-10
Income from Sales / Services	12	-	-
Grants / Subsidies:	13	32,495,000	33,000,000
Fees / Subscriptions	14	-	-
Income from Investments(income on investments from earmarked / endowment Funds)	15	-	-
Income from Royalty, Publications etc.,	16	-	-
Interest earned	17	2,055,923	3,078,044
Other Income	18	29,058	331,232
Increase / (decrease) in stock of finished goods and work-in-progress	19	-	-
TOTAL (A)		*34,579,981*	36,409,276
B - EXPENDITURE			
Establishment Expenses	20	13,612,593	12,843,133
Other Administrative Expenses etc.,	21	9,250,862	7,344,115
Expenditures on Grants, Subsidies etc.,	22	23,725,827	27,311,452
Interest	23	-	-
TOTAL (B)		*46,589,282*	47,498,700
C.BALANCE BEING ~~SURPLUS /~~ DEFICIT CARRIED TO CORPUS / CAPITAL FUND (A-B)		**(12,009,301)**	**(11,089,424)**
NOTES ON ACCOUNTS	24		

As per our report of even date,
for B.R.V.Goud & Co.,
Chartered Accountants,

(Dr PRAVEER ASTHANA)
DIRECTOR

(K.R.SHANKAR)
ACCOUNTS OFFICER

(A.B.SHIVA SUBRAMANYAM)
PARTNER

PLACE :BANGALORE
DATE :06.07.2011

CENTRE FOR SOFT MATTER RESEARCH (Formerly known as Centre for Liquid Crystal Research)
JALAHALLI, BANGALORE - 560 013

RECEIPTS AND PAYMENTS FOR THE PERIOD / YEAR ENDED 31ST MARCH, 2011

(Amount in Rupees)

RECEIPTS		As at 31.03.2011	As at 31.03.2010	PAYMENTS		As at 31.03.2011	As at 31.03.2010
I Opening Balances				**I. Establishment Expenses**		13,612,593	12,843,133
1) Cash in Hand	-	Nil	Nil				
				II Administrative Expenses		9,250,862	7,595,564
2) Bank Balances		2,190,510					
a) Indian Bank	1,953		1,000	**III Fixed Assets (Additions)**		23,725,827	27,311,452
b) State Bank of India	950,373		8,388,975				
c) State Bank of Mysore 1	1,198,056		14,894,048	**IV A) Remittances/Refunds etc.,**		485,224	
d) State Bank of Mysore 2	40,128		10,390	a) Earnest Money Deposit	149,474		10,000
				b) Security Deposit	335,750		15,869
				B) Remittances/Refunds etc.,		2,012,458	3,153,299
II Grants-in-aid from DST, Govt of India		32,495,000	33,000,000	c) Contributory Provident Fund	630,674		
				d) Income Tax Deducted at source			
III Interest Earned		2,055,923		from staff, contractor & rent	760,262		
a) On Savings Bank Accounts	89,762		75,285	e) Professional tax	71,950		
b) On Fixed/Term Deposits	1,966,161		3,002,759	f) Advance to suppliers/others etc.,	345,510		
				g) Staff Advances	132,893		Nil
IV Other Income		18,882		h) New Pension Scheme Tier 1	71,169		Nil
a) Hostel Room Rent recovery	2,700		4,668				
b) License Fee	8,406		12,867				
c) Recovery of Electricity & Water Cha	1,540		44,539	**V Investments**			
d) Miscellaneous Receipts	6,236		13,697	Fixed/Term Deposits opened		44,433,513	83,268,942
e) Overheads recovery on project							
(SERC CVYI)	-	Nil	300,000	**VI Earmarked Project Expenses**		977,833	1,206,935
f) Fellowship CSIR	-	Nil	236,400				
				VII Closing Balance			
V A) Other Recoveries etc.,		269,114		1) Cash in Hand	-	Nil	Nil
1) Earnest Money Deposit	72,099		237,277	2) Bank Balances		730,972	
2) Security Deposit	197,015		93,452	a) Indian Bank	29,817		1,953
B) Other Recoveries etc.,		2,138,533	3,038,383	b) State Bank of India	618,201		950,373
c) Contributory Provident Fund	630,674			c) State Bank of Mysore 1	17,086		1,198,056
d) Income Tax Deducted at source				d) State Bank of Mysore 2	64,868		40,128
from staff, contractor & rent	760,262			e) Bank of India	1,000		Nil
e) Professional tax	71,950						
f) Advance to suppliers/others etc.,	471,585						
g) Staff advance	132,893		Nil				
h) New Pension Scheme-Tire 1	71,169		Nil				
C) Other Recoveries etc.,							
i) Refund of TDS		25,290	Nil				
VI Investments							
a) Fixed/Term deposits matured		54,780,697	72,750,964				
b) Sale of Fixed Asset	-	Nil	23,000				
VII Grants/Financial Assistances		1,255,333					
received for Earmarked Projects							
a) SERC(2004-05) Project	-	Nil	700,000				
b) SERC (CVY1) Project	400,000		-				
c) Indo-Bulgarian Project	-	Nil	166,000				
d) Discussion Meeting (DST & GOI)	-	Nil	600,000				
e) CSIR (2162_CVY3) Project	175,333		-				
f) WOS-A-1 (USH) Project	680,000						
			-				
TOTAL		**95,229,282**	**137,595,704**	**TOTAL**		**95,229,282**	**137,595,704**

As per our report of even date
for M/s. B.R.V.Goud & Co.,
Chartered Accountants,

(Dr.PRAVEER ASTHANA)
DIRECTOR

(K.R.SHANKAR)
ACCOUNTS OFFICER

(A.B.SHIVA SUBRAMANYAM)
PARTNER

PLACE :BANGALORE
DATE :06.07.2011

CENTRE FOR SOFT MATTER RESEARCH (Formerly known as Centre for Liquid Crystal Research)
JALAHALLI, BANGALORE - 560 013

SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31ST MARCH, 2011

(Amount in Rupees)

		As at 31.03.2010	As at 31.03.2009
SCHEDULE 1 - CORPUS / CAPITAL FUND:			
As Per Previous Balance Sheet		112497673	108126054
ADD: Fixed Assets purchased during the year		23725827	27311452
		136223500	135437506
LESS: Excess of Expenditure over Income for the year		12009301	11089424
Depreciation for the year		13754033	11850409
	TOTAL	110460166	112497673
SCHEDULE 2 - RESERVES AND SURPLUS:	**TOTAL**	-	-
SCHEDULE 3 - EARMARKED / PROJECT FUNDS:	**TOTAL**	5592909	5949337
(See Annexure A for details)			
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 - Professional Tax		-	-
2) Other Liabilities - Security Deposit		337457	553566
	TOTAL (A)	337457	553566
B) **PROVISIONS:**		-	-
	TOTAL (B)	0	-
	TOTAL (A+B)	337457	553566
SCHEDULE 8 - FIXED ASSETS	**TOTAL**	83388226	74050359
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			
Current Account		-	-
Deposits Account (includes margin money)		31803185	42150369
Savings Accounts:			
Bank of India (Malleswaram)		1000	-
Indian Bank (BEL Road)		29817	1953
SBI (Jalahalli)		618201	950373
SBM (RMV Extn)		17086	1198056
SBM (Vyalikaval)		64868	40128
	TOTAL (A)	32534157	44340879

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:		44409	170484
a) K P T C L Deposit (SERC/CLCR)		347740	347740
b) Telephone		76000	76000
3) Claims Receivable: Tax Deducted at Sources		-	15114
	TOTAL (B)	468149	609338
	TOTAL (A+B)	33002306	44950217
SCHEDULE 12 - INCOME FROM SALES / SERVICES:	**TOTAL**	-	-
SCHEDULE 13 - GRANTS / SUBSIDIES:			
(Irrevocable Grants & Subsidies Received)			
Dept of Science & Techonolgy Government of India	**TOTAL**	32495000	33000000
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		1966161	3002759
2) On Savings Accounts - Nationalised Bank		89762	75285
	TOTAL	2055923	3078044
SCHEDULE 18 - OTHER INCOME:			
Licence Fee/Hostel Room rent recovery		11106	17535
Miscellaneous Income		16412	13697
Electricity & Water Charges Recovery		1540	300000
	TOTAL	29058	331232
SCHEDULE 19 - INCREASE (DECREASE) IN STOCK OF FINISHED GOODS & WORK IN PROGRESS:		-	-
SCHEDULE 20 - ESTABLISHMENT EXPENSES:			
1) Salaries and Wages to Staff		9777749	9987972
2) Medical Expenses Reimbursed		37324	4611
3) Salaries-Allowances,bonus & Awards		116958	58540
4) Fellowship & Book Grant		3663243	2792010
5) Uniforms to Staff		17319	-
	TOTAL	13612593	12843133
SCHEDULE 21 - OTHER ADMINISTRATIVE EXPENSES,ETC:			
Advertisement Charges		61935	57985
Audit Fee		19854	19854
Bank Charges		26225	20306
Chemicals, Glasswares & Consumables etc.,		2358203	1029242
Local Conveyance		235287	278380
Customs Duty/other Levies		85786	48645
Electricity & Water		1211053	1015484
Hospitality		51492	78865
House Keeping Charges		775176	315000
Insurance on Building & Equipments		0	36982
Journals & Periodicals		1573787	579883
Loss on sale of Assets		-	31490
N.M.R. Recording & Sample analysis charges		188437	130000

Clearing and forwarding		45280	103612
Postage		32484	33752
Professional Charges/Honorarium		75550	0
Registration & Annual Fee		67050	18075
Rent of Hostel building		264000	260000
Repairs & Maintenance of Building		219141	1105129
Repairs & Maintenance of Equipments		307822	779520
Security Charges		715678	387809
Seminar and Conferences & Foreign Travel		214205	169443
Stationery & Printing		206687	240002
Telephone Charges		254014	180118
Travel Expenses		261716	424539
	TOTAL	9250862	7344115
SCHEDULE 22 - EXPENDITURE ON GRANTS, SUBSIDIES ETC: (Fixed assets)		23725827	27311452
SCHEDULE 23 - INTEREST:		-	-

CENTRE FOR SOFT MATTER RESEARCH (Formerly known as Centre for Liquid Crystal Research)
JALAHALLI, BANGALORE - 560 013

SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31ST MARCH, 2011

Annexure - A to Schedule 3

(Amount in Rupees)

SCHEDULE 3 - EARMARKED / PROJECTS FUNDS	PROJECT / WISE BREAKUP													CURRENT YEAR TOTAL	PREVIOUS YEAR
	SERC	SERC (2004-05)	SERC (CVY1)	INDO-US	INDO-US (SKP)	INDO - JAPAN	CSIR (NMITLI)	CSIR (SK)	CSIR (CVY)	CSIR (2162_CVY3)	INDO-BULGARIAN	SERC HL Bhat	WOS-A-1 (USH)		
a) Opening Balance of the Funds	2063231	143318	1378267	417579	175071	175319	1060881	27849	17931	178109	135319	176462	0	5949336	6436092
b) Additions to the Funds:															
i) Grants	-	-	400000	-	-	-	-	-	-	175333	-	-	680000	1255333	1466000
ii) Income from Investments made on Account of India	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
TOTAL (a+b)	2063231	143318	1778267	417579	175071	175319	1060881	27849	17931	353442	135319	176462	680000	7204669	7902092
c) Utilisation/Expenditure towards objectives of Funds:															
i) Capital Expenditure															
Fixed Assets	-	-	-	-	-	-	-	-	-	-	-	-	-		
Others															
ii) Revenue Expenditure															
Salaries, Wages and Allowances etc.	-	-	252360	-	-	-	-	-	-	194226	64415	-	79,032	590033	800414
Consumables	-	-	387800	-	-	-	-	-	-	-	-	-	-	387800	106521
Depreciation	211146	21498	170716	14363	26268	-	159144	4177	2733	23882	-	-	-	633927	745820
Overheads	-	-	-	-	-	-	-	-	-		-	-	-	0	300000
TOTAL (c)	211146	21498	810876	14363	26268	0	159144	4177	2733	218108	64415	0	79032	1611760	1952755
NET BALANCE AT THE YEAR END (a+b-c)	1852085	121820	967391	403216	148803	175319	901737	23672	15198	135334	70904	176462	600968	**5592909**	5949337

CENTRE FOR SOFT MATTER RESEARCH (Formerly known as Centre for Liquid Crystal Research)
JALAHALLI, BANGALORE - 560 013

SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31ST MARCH, 2011

SCHEDULE - 8 : FIXED ASSETS (Amount in Rupees)

DESCRIPTION	GROSS BLOCK W.D.V. as on 31.03.2010	Additions during Total additions	Total	Rate	Depreciation for the year	NET BLOCK W.D.V. as on 31.03.2011
A. CLCR :						
CIVIL WORKS						
Aluminium Partitions	1,119,485	401,815	1,521,300	10	152,130	1,369,170
Brick Base(Partitions)	108,054	60,175	168,229	10	16,823	151,406
Construction of Cycle Stand	66,376	-	66,376	10	6,638	59,738
Construction of Shed	68,403	-	68,403	10	6,840	61,563
Vinyl Flooring	121,139	206,215	327,354	10	32,735	294,619
Other Miscellaneous Works	1,904,659	221,094	2,125,753	10	212,575	1,913,178
BUILDING (Main & Annexe)	6,972,901	1,961,084	*8,933,985*	10	893,399	8,040,586
ELECTRICAL INSTALLATIONS			-			
Air Conditioner	345,177	635,391	980,568	15	147,085	833,483
Computers	217,272	834,727	1,051,999	60	631,199	420,800
Fume Cupboard	74,785	-	74,785	10	7,479	67,306
Generator Set	988,452	-	988,452	15	148,268	840,184
FURNITURE & FIXTURES			-			
Carpentary Works	421,690	34,758	456,448	10	45,645	410,803
Furniture & Fixtures	756,494	538,453	1,294,947	10	129,495	1,165,452
GENERAL EQUIPMENTS			-			
Equipment	2,281,318	1,747,124	4,028,442	15	604,266	3,424,176
Workshop Equipment	179,608	-	179,608	15	26,941	152,667
SCIENTIFIC EQUIPMENTS	54,198,441	17,084,991	*71,283,432*	15	10,692,515	60,590,917
Total - (A)	**69,824,254**	**23,725,827**	**93,550,081**		**13,754,033**	**79,796,048**
B. SERC PROJECT:						
Electrical Installation	128,016	-	128,016	15	19,202	108,814
Equipment	1,279,196	-	1,279,196	15	191,879	1,087,317
Cycle	431	-	431	15	65	366
Total - (B)	1,407,643	-	1,407,643		211,146	1,196,497
C. INDO US PROJECT:						
Equipment	80,661	-	80,661	15	12,099	68,562
Temperature Controller	6,158	-	6,158	15	924	5,234
Cell Fabrication	8,936	-	8,936	15	1,340	7,596
Total - (C)	95,755	-	95,755		14,363	81,392
D. INDO US (SKP) PROJECT:						
Equipment	175,118	-	175,118	15	26,268	148,850
Total - (D)	175,118	-	175,118		26,268	148,850
E. CSIR (NMITLI) PROJECT:						
Equipment	1,060,854	-	1,060,854	15	159,128	901,726
Computers	27	-	27	60	16	11
Total - (E)	1,060,881	-	1,060,881		159,144	901,737
F. CSIR (SK) PROJECT:						
Equipment	27,846	-	27,846	15	4,177	23,669
Total - (F)	27,846	-	27,846		4,177	23,669
G. CSIR (CVY) PROJECT:						
Equipment	18,219	-	18,219	15	2,733	15,486
Total - (G)	18,219	-	18,219		2,733	15,486
H. SERC (2004-05) PROJECT:						
Equipment	143,318	-	143,318	15	21,498	121,820
Total - (H)	143,318	-	143,318		21,498	121,820
I. SERC (CVY1) PROJECT:						
Equipment	1,138,109	-	1,138,109	15	170,716	967,393
Total - (I)	1,138,109	-	1,138,109		170,716	967,393
J. CSIR (2162_CVY3) PROJECT:						
Equipment	159,216	-	159,216	15	23,882	135,334
Total - (J)	159,216	-	159,216		23,882	135,334
Total - B to J	***4,226,105***	**-**	***4,226,105***		***633,927***	***3,592,178***
Grand Total (A to J)	**74,050,359**	**23,725,827**	**97,776,186**	**-**	**14,387,960**	**83,388,226**

CENTRE FOR SOFT MATTER RESEARCH, JALAHALLI, BANGALORE

SCHEDULES FORMING PART OF THE ACCOUNTS FOR THE YEAR ENDED 31ST MARCH 2011

SCHEDULE 25: SIGNIFICANT ACCOUNTING POLICIES

1. **Accounting Conventions :** The financial statements are drawn up in accordance with historical accounting conventions and on the going concern concept. Cash system is followed to record the Income and Expenditure.

    - According to the decision taken by the Governing Council for Accounting treatment of Grants - in –aid received from Department of Science and Technology to defray the expenses of the Centre, no bifurcation has been made between Revenue Grant and Capital Grant. The total amount of Grant received from the DST during the Fiscal Year 2010-11 has been credited to the Income and Expenditure account of the Centre.

2. **Investments :** Investments are stated at cost. Interests from Investments are accounted on "cash basis".

3. **Fixed assets :** Fixed assets are stated at written down value. Fixed assets shown under Gross Block are recorded at cost of acquisition, inclusive of inward freight, duties, taxes and incidental expenses related to acquisition.

4. **Government Grants / Other Grants :** The Grants are recognized in the accounts on realization basis. The total amount of grant received from DST during the fiscal 2010-11 has been credited to the Income & Expenditure account of the Centre. The conditions stipulated for utilization of Grants-in-aid have been strictly adhered by the Centre.

5. **Depreciation :** Depreciation on Fixed assets has been provided on Written Down Value Method at rates as per Income Tax Rules 1962. Out of the total amount of Depreciation on fixed assets of Rs.1,43,87,960/-, depreciation of Rs. 1,37,54,033/- on general fixed assets of the Centre has been debited to capital fund account and the depreciation on assets pertaining to projects amount to Rs.6,33,927/- has been debited to the Projects fund account. This system is being followed by the Centre since the entire cost of acquisition of fixed assets acquired by the Centre in the respective years of acquisition has been treated as Expenditure on Grants in the Income & Expenditure Account, as a matter of accounting policy, as stated in Note No.6 below.

6. **Capital Expenditure :** All Capital Expenditure incurred during the year amounting to Rs. 2,37,25,827/- for purchase of Fixed Assets is charged to Income & Expenditure Account, under the head "Expenditure on Grants/ Subsidy". The same is again reflected in Fixed Assets schedule by crediting to Capital Fund account.

CONTINGENT LIABILITIES AND NOTES ON ACCOUNTS

1. CONTINGENT LIABILITIES :

1.1 Claims against the Entity not acknowledged as debts	Rs. **Nil**	(Previous year Rs. **Nil**)
1.2 In respect of :		
Bank guarantee given by/on behalf of the Entity	Rs. **Nil**	(Previous year Rs. **Nil**)
Letter of Credit opened by Bank on behalf of the Entity	Rs. **Nil**	(Previous year Rs. **Nil**)
Bills discounted with bands	Rs. **Nil**	(Previous year Rs. **Nil**)
1.3 Disputed Demands in respect of :		
Income tax	Rs. **Nil**	(Previous year Rs. **Nil**)
Sales tax	Rs. **Nil**	(Previous year Rs. **Nil**)
Municipal taxes	Rs. **Nil**	(Previous year Rs. **Nil**)
1.4 In respect of claims from parties for non-execution of orders, but contested by the Entity	Rs. **Nil**	(Previous year Rs. **Nil**)

2. CAPITAL COMMITMENTS :

Estimated value of contracts remaining to be executed on Capital account and not provided for (net of advances)	Rs. **Nil**	(Previous year Rs. **Nil**)

3. LEASE OBLIGATIONS :

Future obligations for rentals, under finance lease arrangements, for plant and machinery amounts to	Rs. **Nil**	(Previous year Rs. **Nil**)

4. CURRENT ASSETS, LOANS AND ADVANCES :

In the opinion of the management, the current assets, loans and advances have a value on realisation in the ordinary course of business, equal at least to the aggregate amount shown in the Balance Sheet.

5. TAXATION : No provision for Income Tax has been considered necessary as Centre for Soft Matter Research (formerly called Centre for Liquid Crystal Research) has been registered under Sec. 10(21) and Sec. 12A of Income Tax Act, 1961.

6. FOREIGN CURRENCY TRANSACTIONS :

6.1 Value of Imports " Calculated on C I F Basis"	
a) Capital goods	Rs. 1,48,77,376/-
b) Stores. Spares and Consumables	Rs. 23,44,312/-
6.2 Expenditure in Foreign Currency :	
a) Travel	Rs. 23,750/-
b) Remittances and Interest payment to Financial Institutions/Banks in Foreign Currency	Nil
6.3 Earnings :	
Value of Exports "Calculated on F O B basis"	Nil

7. **Presentation of Accounts** : The Financial Statements are presented in the format prescribed by the Department of Science and Technology for all Central Autonomous Organizations, vide their letter No. A1/Misc/004 /2002 dated 26.03.2002.

8. All the paisa are rounded off to the nearest Rupee.

9. Previous year's figures have been regrouped wherever necessary to suit this year's groupings.

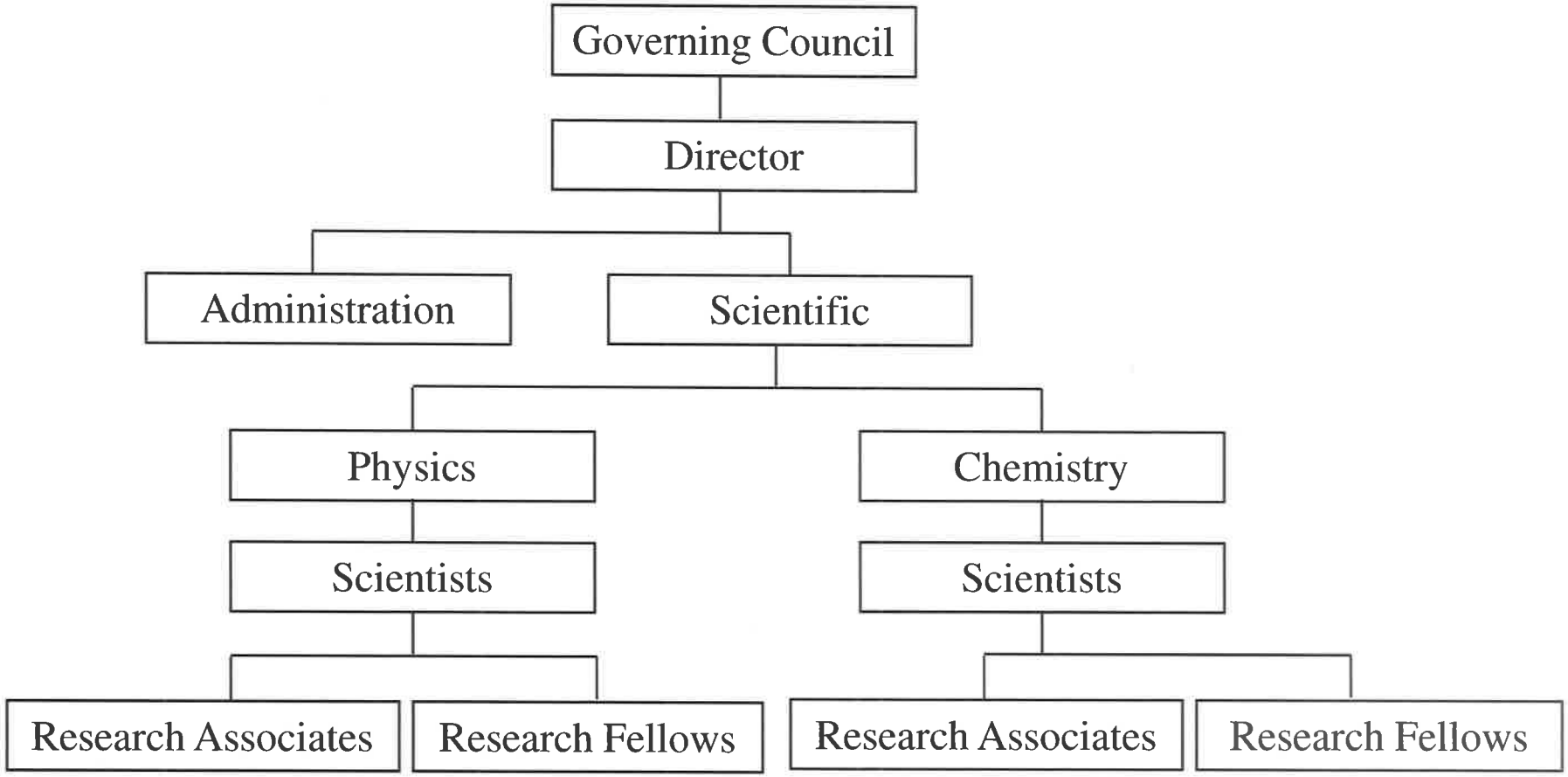
10. Schedules 1-24 are annexed to and form an integral part of the Balance Sheet as at 31st March 2011 and the Income and Expenditure Account for the year ended on that date.

As Per out report of even date,
for B.R.V. Goud & Co.,
Chartered Accountants

PLACE: Bangalore
DATE : 06/07/2011

(A.B. SHIVA SUBRAMANYAM)
PARTNER

Centre for Soft Matter Research (CSMR)
Organisation Chart



CENTRE FOR SOFT MATTER RESEARCH
P.B.No.1329, Prof. U.R.Rao Road
Jalahalli
Bengaluru – 560 013
Tel: 080-2838 6582, 2838 1119, 2838 1347, 2838 2337, 2345 6403
Fax: 080-2838 2044
E-mail: admin@csmr.res.in
Website: http://www.csmr.res.in

मृदु पदार्थ अनुसंधान केंद्र
डाक बॉक्स १३२९
प्रो॰ यू॰ आर॰ राव मार्ग
जालहल्ली
बेंगलूरू – ५६० ०१३
फोन: **080-2838 6582, 2838 1119, 2838 1347, 2838 2337, 2345 6403**
टेलीफाक्स : **080-2838 2044**
ईमेल : **admin@csmr.res.in**
वेब : **http://www.csmr.res.in**