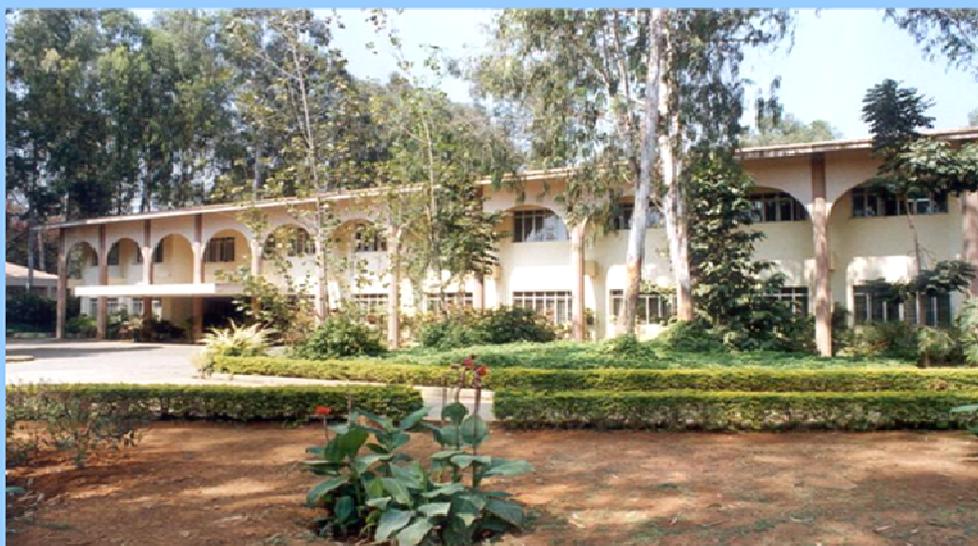


# Centre for Soft Matter Research

Bengaluru

मृदु पदार्थ अनुसंधान केंद्र

बेंगलूरु



Annual Report  
2011 - 2012

वार्षिक रिपोर्ट  
२०११ - २०१२

**CENTRE FOR SOFT MATTER RESEARCH**

**BENGALURU**

**ANNUAL REPORT**

**2011 – 2012**

## THE GOVERNING COUNCIL (2011-2012)

**Prof. R. Narasimha FRS**  
Chairman, EM Unit  
Jawaharlal Nehru Centre for  
Advanced Scientific Research  
Jakkur  
BENGALURU - 560 064

**Chairman**

**Prof. N. Kumar**  
Emeritus Professor  
Raman Research Institute  
Sadashivnagar  
BENGALURU - 560 080

**Member**

**Dr. T. Ramasami**  
Secretary to the Government of  
India  
Department of Science and  
Technology  
Technology Bhavan  
New Mehrauli Road  
NEW DELHI - 110 016

**Member**

**Prof. K. R. Sarma**  
Advisor (Technology)  
Samtel Color Ltd  
204/B, Manjeera Heights  
N.T.R. Nagar  
Near R.R. District Court  
HYDERABAD - 500 074

**Member**

**Prof. P. Rama Rao**  
Distinguished Professor  
International Advanced Research  
Centre for Powder Metallurgy &  
New Materials  
Balapur  
HYDERABAD - 500 005

**Member**

**Ms. Anuradha Mitra**  
Joint Secretary &  
Financial Advisor  
Department of Science and  
Technology  
Technology Bhavan  
New Mehrauli Road  
NEW DELHI - 110 016

**Member**

**Prof. C. L. Khetrapal**  
Director, Centre for Biomedical  
Magnetic Resonance  
Sanjay Gandhi PG Institute of  
Medical Sciences  
Raibareli Road  
LUCKNOW - 226 014

**Member**

**Shri I. V. Sarma**  
Director (R & D)  
Bharat Electronics Limited  
Outer Ring Road, Nagawara  
BENGALURU - 560 045

**Member**

**Prof. K. N. Pathak**  
Professor Emeritus  
Department of Physics &  
Former Vice-Chancellor  
Panjab University  
CHANDIGARH - 160 014

**Member**

**Dr. Praveer Asthana**  
Acting Director  
Centre for Soft Matter Research  
P.B. No.1329, Jalahalli  
BENGALURU - 560 013

**Member-  
Secretary**

# CONTENTS

		PAGE NO.
	FOREWORD	
1	INTRODUCTION .....	1
2	CORE FUNDED PROJECT .....	2
3	RESERVATION AND OFFICIAL LANGUAGE .....	2-3
4	RESEARCH ADVISORY BOARD .....	3
5	FINANCE COMMITTEE .....	3-4
6	RESEARCH AND DEVELOPMENT ACTIVITIES .....	4-49
7	SPONSORED PROJECTS .....	50-51
8	WOMEN'S DAY .....	51-52
9	NATIONAL SCIENCE DAY .....	52-57
10	PROF. S. CHANDRASEKHAR MEMORIAL LECTURE .....	58-60
11	INTERNATIONAL YEAR OF CHEMISTRY .....	61
12	STUDENTS' PROGRAMME .....	61-62
13	AWARDS / HONORS .....	62-63
14	POPULARIZATION OF SCIENCE .....	63-68
15	VISITS ABROAD .....	69
16	SEMINARS / TALKS GIVEN AT OTHER INSTITUTES .....	69-73
17	LECTURES BY VISITORS .....	73-74
18	LIST OF SCIENTISTS AND RESEARCHERS .....	74-75
19	ADMINISTRATIVE STAFF .....	75
20	PUBLICATIONS DURING 2011-2012 .....	76-80
21	STATEMENT OF ACCOUNTS AND BALANCE SHEET .....	81-93



## **FOREWORD**

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

The Annual Report for the year 2011-2012 highlights the research and development activities, scientific programmes of the Centre, and lists the output of the Centre such as the academic activities and research publications for the period 1 April 2011 to 31 March 2012.

It is nearly two years since the Centre's name was changed from "Centre for Liquid Crystal Research" to "Centre for Soft Matter Research" and accordingly the research activities have enlarged from liquid crystals to gels, ferrogels, polymers, thin films, nanomaterials, nanoweeds etc. In addition, newer activities are initiated in multiferroic materials, colossal magnetoresistance materials, reduced graphene oxide thin films and so on. The aim of the Centre is to strengthen research activities in all these areas.

Bengaluru

PRAVEER ASTHANA

## **1. INTRODUCTION**

The Centre, formerly known as Centre for Liquid Crystal Research (CLCR), started functioning as a Scientific Society registered under the Karnataka Societies Act. It was funded by an ad-hoc grant from the Department of Science and Technology, Government of India, project grants from SERC and from the funds made available by the Raman Research Institute Trust. The Centre was taken over in 1995 by the Govt. of India, and was brought under the administrative control of the Department of Information Technology. In the year 2003, the Centre was converted to an autonomous institution under the administrative control of the Department of Science and Technology (DST), Ministry of Science and Technology. The Centre was renamed as “Centre for Soft Matter Research (CSMR)” with effect from 1 September 2010 in order to expand the scope of its research programmes keeping in view the current international trends in research. The new name was approved by DST and the amendment was registered by the Registrar of Societies, Government of Karnataka on 28 April 2010. DST has been providing core support in the form of grant-in-aid for conducting basic and applied research in soft matter and related areas. The objective of the Centre is to focus on basic science, and to develop a bias towards technology, in line with the international trends in research on Soft Matter including liquid crystal materials.

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

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

## **2. CORE FUNDED PROJECT**

The Department of Information Technology, Govt. of India, in its proposal submitted to the Planning Commission provided for CLCR, an outlay of Rs.12.88 crores for the 10<sup>th</sup> 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 was converted into an autonomous institution 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 11<sup>th</sup> 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	415.00	373.00	442.00	586.00*	2100.00
(FE 84.00)	(FE 179.00)	(FE 111.00)	(FE 151.00)	(FE 262.00)	(FE 787.00)

\* During the year 2011-12, a grant of Rs. 576.74 lakhs was released by DST.

## **3. RESERVATION AND OFFICIAL LANGUAGE**

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

The Centre has one SC/ST employee working under Group C.

## HINDI DAY

The Centre observed the Hindi Divas on 14 September 2011. On this occasion, Smt. Shruti Sarda, Quality Assurance Engineer, Aditi Technologies, Bangalore, gave a talk titled " **विश्व को भारत की देन** ".

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 Presently, Director (R&D), Bharat Electronics Limited	Member
7.	Prof. K. A. Suresh Centre for Soft Matter Research	Convener

## 5. FINANCE COMMITTEE

The fourth meeting of the Finance Committee with the following members was held on 31 January 2012.

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

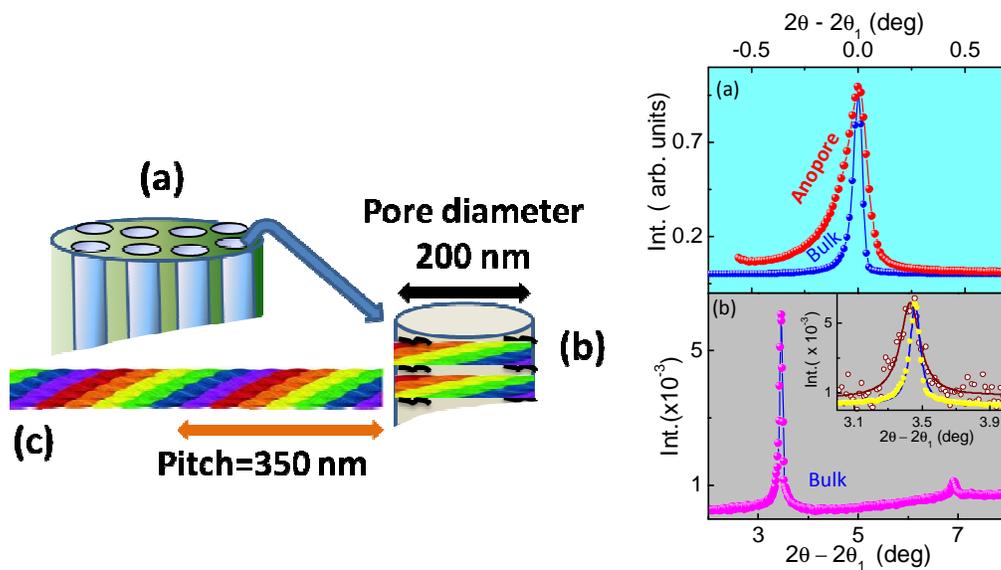
## 6. RESEARCH AND DEVELOPMENT ACTIVITIES

### **6.1 CONFINEMENT DRIVEN EFFECTS IN A ROOM TEMPERATURE FERROELECTRIC LIQUID CRYSTAL: X-RAY, LINEAR AND NON-LINEAR DIELECTRIC INVESTIGATIONS**

The smectic C\* (SmC\*) ferroelectric liquid crystal exhibiting two natural length scales, one at a nm level, and the other generally in the mesoscopic range, is well studied to investigate the effects of finite size and confinement. With this background, we have performed Xray, linear and non-linear dielectric constant measurements on a room temperature ferroelectric liquid crystalline phase. Confinement of the liquid crystal was realized in commercially available Anodisc (Whatman) membranes with a pore size of 200 nm, thickness of 60  $\mu\text{m}$ , 50% porosity and a pore density of  $10^9 \text{ cm}^{-2}$ . The aspect ratio (pore diameter/membrane thickness) of the channels in these membranes is over two orders of magnitude and therefore alludes a low dimensionality (quasi 1D) to the system. The used liquid crystal, prepared by the Russian collaborator, exhibits SmC\* helical pitch of  $p \sim 200 \text{ nm}$ , which is comparable to the pore dimension of the membrane. Xray measurements show several interesting results including unusually strong harmonic reflections, substantial broadening of the peak profile, correlation length smaller than the pore diameter, etc. The data suggest that the smectic A -SmC\* transition could be very close to a tricritical point in the bulk, and moving away from it upon

confinement. The dielectric studies show that confinement accelerates the relaxation dynamics of both the soft and Goldstone modes, although with a reduced strength. The nonlinear component of the dielectric constant, realized for the first time in a porous confinement environment, exhibits qualitatively different thermal behaviour in the bulk and Anopore samples.

This work was carried out in collaboration with E. P. Pozhidaev of the P.N. Lebedev Physical



*Left panel: Schematic diagram to illustrate the confinement of the ferroelectric liquid crystal in an Anopore membrane (a,b). The rope like structure (c) points to the helix superimposed on the tilted molecules in the SmC\* phase; the colour coding is used to suggest the variation of the azimuthal angle.*

*Right panel: X-ray diffraction profiles in the low angle region for the bulk (filled symbol) and confined (open symbol) samples, shown in terms of reduced diffraction angle. (a) The lowest angle peak, with a Bragg angle  $2\theta_1$ , corresponds to the layer thickness of the smectic phase. Upon confinement the profile gets broadened. (b) The second and third harmonic peaks with unusual strength seen for the bulk sample. The strength of the second harmonic is comparable in the bulk and Anopore samples (panel c)*

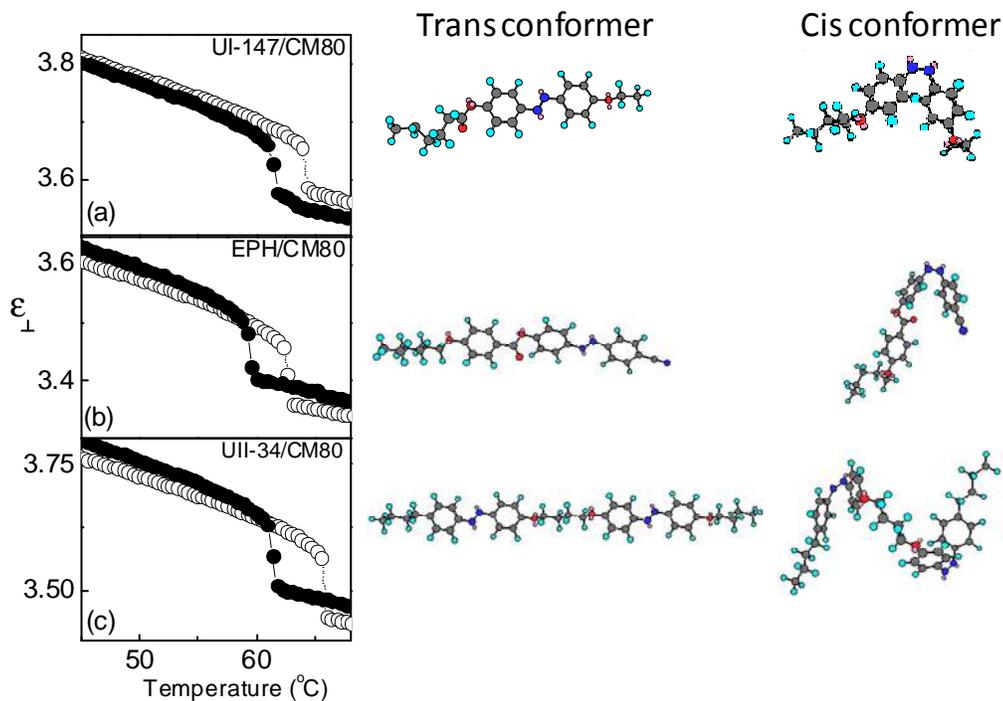
Institute of Russian Academy of Sciences, Moscow, Russia. This work is published: M. Vijay Kumar, S. Krishna Prasad and D.S. Shankar Rao, E. P. Pozhidaev, *Phase Transitions* (in Press).

**Investigators : S.Krishna Prasad, M.Vijay Kumar, D.S.Shankar Rao**

## **6.2 FIRST OBSERVATION OF ENHANCEMENT OF THE BEND ELASTIC CONSTANT UPON PHOTOISOMERIZATION IN PHOTSENSITIVE SOFT MATERIALS**

Optical absorption, thermo-optical and dielectric studies have been performed on three guest–host nematic mixtures featuring photo-sensitized flexoelectric polarization. A room temperature nematic with a negative dielectric anisotropy served as the host material. Three different azo-dye compounds, also exhibiting liquid crystallinity were employed as the low-concentration guest component in the mixtures. In each case, illumination of the sample with actinic (UV) light leads to strong photoisomerization driven effects. Strong correlations among the shift of the isotropic–nematic phase transition temperature, UV-induced changes in the dielectric constant values, population of the cis isomers, and the change in the length of the azo-dyes upon UV illumination, have been found. The change in the sign and magnitude of the dielectric constant due to photoisomerization is governed by the change in the orientation of the dipole moment before and after UV illumination, and thus can be tuned. The most significant result of the study is the first observation of the lowering of the bend elastic constant upon photoisomerization, a feature ascribed to the formation of the bent-shaped cis isomers. In guest-host mixtures consisting of only 1% of the UV active component, the photo-driven effect is seen to cause up to 7% lowering of the bend elastic constant.

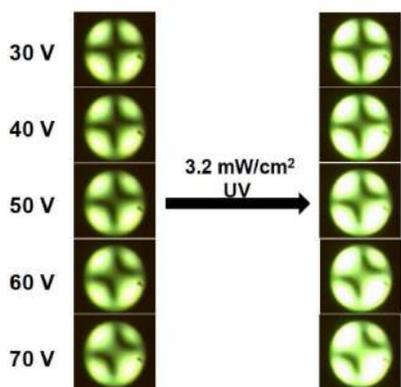
This work was carried out in collaboration with Y. G. Marinov, G. B. Hadjichristov, and A. G. Petrov of the Bulgarian Academy of Sciences, Sofia, Bulgaria, and is published: S. Sridevi, U. S. Hiremath, C. V. Yelamaggad, S. Krishna Prasad, Y. G. Marinov, G. B. Hadjichristov, and A. G. Petrov, *Mater. Chem. Phys.* **130**, 1329 (2011).



Left panels: Thermal variation of the permittivity without (open symbols) and with (filled symbols) UV illumination for three different guest-host mixtures. The middle and right panels show the molecular shapes of the photoactive dopants in their equilibrium trans, and photo-driven cis states.

**Investigators :** S.Krishna Prasad, S.Sridevi, U.S.Hiremath and C.V.Yelamagad

### 6.3 DIRECT OBSERVATION OF PHOTOFLEXOELECTRIC EFFECT



Conoscopic images demonstrating the flexoelectric effect and its enhancement by photoisomerization

In a nematic system composed of a photoactive component, we have established by direct optical methods that there is a substantial (nearly a factor of 2) increase in the flexoelectric constant. As seen in the conoscopic images on the left, increasing the electric field increases the separation between the isogyres, pointing to the increase in the flexoelectric effect. More importantly, illumination with actinic light, and the consequent photoisomerization of the photoactive

component results in a significant enhancement of the effect. It is further shown that the

molecular structure of the photoactive component plays a significant role in governing the magnitude of this effect.

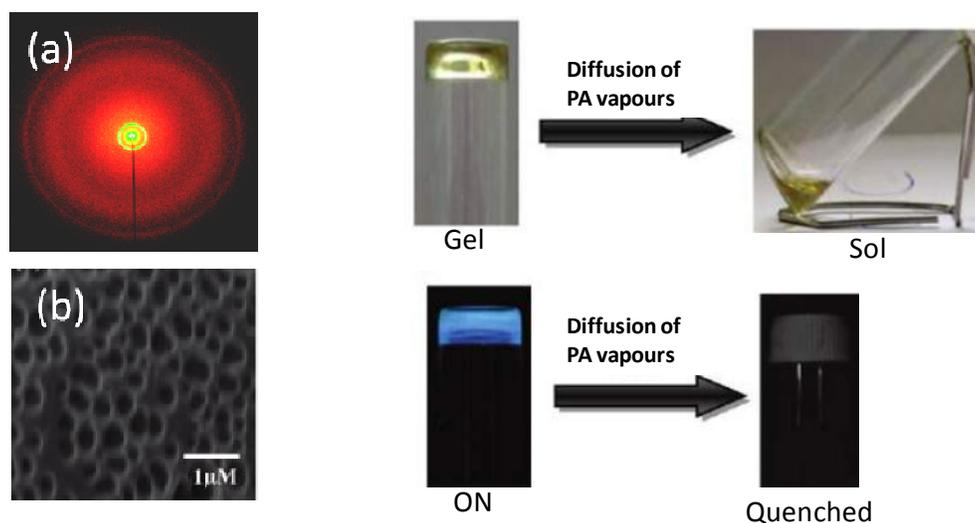
This work was carried out in collaboration with Y. G. Marinov, G. B. Hadjichristov, and A. G. Petrov of the Bulgarian Academy of Sciences, Sofia, Bulgaria, and is published: A. G. Petrov, Y.G. Marinov, G. B. Hadjichristov, S. Sridevi, U. S. Hiremath, C. V. Yelamaggad, and S. K. Prasad, *Mol. Cryst. Liq. Cryst.* **544**, 3/[991] (2011).

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

#### **6.4 SELF-ASSEMBLY AND SENSING APPLICATIONS**

A triphenylene-based discotic liquid crystal bearing 1,2,3-triazole groups has been employed to create an organogel with a porous network. The parent liquid crystal exhibits a columnar phase with significant ordering of the discs within the column. The organogel formed with cyclohexane exhibits a well defined porous network as evidenced by SEM images. If the gel is exposed to vapors of picric acid without actually a direct gel analyte contact, a complete gel to sol transition was observed in 8 hours. Such a transition was also followed by a strong fluorescence quenching. The strong emission of host in its nonaggregated form makes it a promising fluorescence sensory material for nitroaromatic compounds.

This work was carried out in collaboration with Vandana Bhalla, Hardev Singh, Manoj Kumar, Guru Nanak Dev University, Amritsar, Punjab, and is published: Vandana Bhalla, Hardev Singh, Manoj Kumar and S. Krishna Prasad, *Langmuir* **27**, 15275 (2011).



Left: (a) Xray and (b) SEM images revealing the columnar structure and porous network respectively. Right: Gel-sol transition caused by the diffusion of picric acid vapours, and the consequent quenching of the fluorescence.

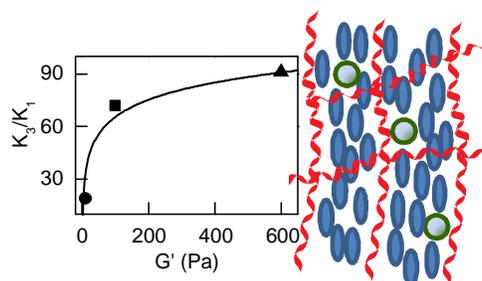
**Investigator : S.Krishna Prasad**

### **6.5 RHEOLOGICAL, ELECTRICAL AND MAGNETIC MEASUREMENTS ON LIQUID CRYSTALLINE FERROGELS**

Incorporation of magnetic particles into a soft organic medium, mainly a fluid, has been attracting a great deal of attention owing to the potential applications of magnetic materials as well as the associated basic science. Investigations on the combination of liquid crystals (LC) and ferro particles received a momentum after the suggestion by Brochard and de Gennes that it should be possible to realize a stable ferronematic phase by having a uniform dispersion of a small concentration of ferromagnetic grains in a host nematic LC. The expectation was that a ferromagnetic state would be induced due to a strong coupling between the orientation of the magnetic grains and the nematic ordering in which the director orientation can be controlled by weak external magnetic fields. The experimental realization of stable dispersion of magnetic particles in the LC medium is frustrated by a tendency of the particles to segregate. We have developed a technique to overcome this

problem through gelation of the ferronematic fluid. Added advantages of these systems are the mechanical rigidity of a gel and the anisotropic characters of the ferronematic. Detailed calorimetric, XRD, dielectric, elastic, rheological and magnetic measurements on a nematic liquid crystal (NLC) doped with FePt nanoparticles and an organogelator have been carried out and the results are summarized below:

- a. The Frank bend elastic constant increases by two orders of magnitude indicating the mechanical rigidity of the gels.
- b. XRD data suggest that the orientational correlations of NLC are slightly strengthened by the presence of the particles and the gelator.



*Strong increase of the Frank elastic constant ratio and its logarithmic dependence on the storage modulus in a liquid crystalline nematic gel composed of ferromagnetic nanoparticles.*

- c. The magnetic measurements reveal that the superparamagnetic feature of the FePt particles is weakened in the ferrogels suggesting the local environment of the particles has an important role in quenching the thermal fluctuations which in turn influences their magnetic interaction.

This work was carried out in collaboration with Mr. Nitesh Kumar and Prof. A. Sundaresan, JNCASR, Bangalore. This work is published: Enhanced Frank Elasticity and Storage Modulus in a Diamagnetic Liquid Crystalline Ferrogel, R. Bhargavi, Geetha G. Nair, S. Krishna Prasad, Nitesh Kumar and A. Sundaresan, *Soft Matter*, **7**, 10151–10161 (2011).

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

## **6.6 ANCHORING TRANSITIONS IN NEMATIC GELS**

Realizing preferential alignment or anchoring of liquid crystalline (LC) molecules at surfaces is of fundamental importance for electro-optic applications of LC devices. The anchoring of the LC director, usually achieved by a mechanical or photo-treatment of a deposited thin chemical

layer on a substrate, can be parallel (planar), orthogonal (homeotropic) or tilted with respect to the surface. The anchoring can also be caused by interfaces, such as the LC-air, or LC-polymer fibre interface. While the general aim for applications is to retain the achieved anchoring over the entire temperature range of operation of the device, a change in the direction of anchoring - referred to as anchoring transition - has been known to be driven by temperature or concentration of the material. Especially interesting among the ways to obtain anchoring transitions are those driven by the nature of polymer surface; they have attracted much attention, owing to the fact that polymer surfaces are often employed to achieve the preferential alignment of molecules. In this work, we are investigating anchoring transition triggered by gelation of a nematic liquid crystal (NLC) with an organic gelator. We have used polarizing microscopy, dielectric spectroscopy and Frederikz transition measurements as experimental tools to probe the anchoring transitions. XRD studies indicate that there is an associated increase in the smectic-like correlation length, suggesting that the change in the anchoring condition is caused by the ability of the gel fibres to orient the molecules in the nematic phase.

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

### ***6.7 RHEOLOGICAL PROPERTIES OF LEXAN POLYCARBONATE FILMS EXPOSED TO ELECTRON BEAM***

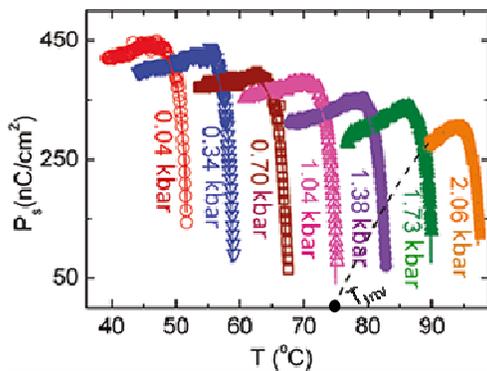
The physical and chemical properties of polymers can be modified by electron beam irradiation. When an electron beam is allowed to pass through a polymeric material, drastic changes in optical, structural, free volume, thermal and other properties have been observed due to crosslinking, chain scission, chain aggregation, molecular emission etc. Lexan polycarbonate (Lexan) is a promising polymer having many desirable properties for different applications such as aircraft canopy, solar cells and solid state nuclear track detector etc. We have carried out rheological measurements of the Lexan polycarbonate (Bisphenol-A-

polycarbonate) films to investigate the modifications in the mechanical properties of the films exposed to different electron beam doses. Measurements were carried out on both pristine and electron irradiated Lexan films. The bulk viscosity and the average molecular weight of the Lexan films were found to decrease while average number of chain scissions per original polymer molecule increases on irradiation.

This is a collaborative work with Dr. Ganesh Sanjeev and Mr. K. Hareesh of Microtron Centre, Department of Studies in Physics, Mangalore University, Mangalagangothri 574199.

**Investigators : Geetha G. Nair and R. Bhagavi**

### 6.8 HIGH-PRESSURE INVESTIGATIONS OF A FERROELECTRIC LIQUID CRYSTAL EXHIBITING A TREND REVERSAL IN THE THERMAL VARIATION OF POLARIZATION



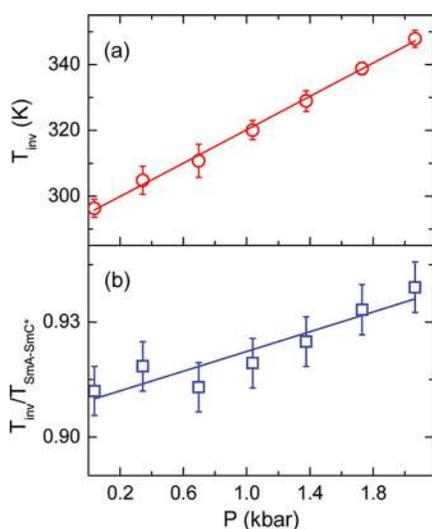
**Figure :** Temperature dependence of the  $P_s$  at several pressures. At all pressures, on cooling the sample below the SmA-SmC\* transition,  $P_s$  exhibits a sharp rise and a trend reversal after reaching a maximum, a feature that becomes prominent at higher pressures. The solid lines represent fitting. The possibility of reaching the  $T_{inv}$  point as determined is shown as a dashed line for the highest pressure data set.

We have measured thermal variation of spontaneous polarization ( $P_s$ ), coercive voltage ( $U_{xc}$ ), and rotational viscosity ( $\gamma_0$ ) of a ferroelectric liquid crystal (10PPBN4) as a function of applied pressure.

The material having a high value of  $P_s$  exhibits a trend reversal. As the temperature is lowered below the transition from the smectic A to the smectic C\* (ferroelectric) phase, the spontaneous polarisation  $P_s$  increases to begin with but after reaching a maximum decreases with further

decrease in temperature. Interestingly, the trend reversal feature becomes more dominant as

the pressure is increased. The behaviour is well described by a model developed for materials exhibiting a sign reversal in  $P_s$ . The single characteristic parameter of the model, viz., the ratio of the inversion temperature (at which  $P_s$  changes sign), to the transition temperature, is seen to increase with pressure, corroborating predominance of trend reversal at elevated pressures observed experimentally. Further, at a fixed reduced temperature with respect to the smectic A – smectic C\* transition, all three parameters,  $P_s$ ,  $U_{xc}$ , and  $(\gamma_0)$ , decrease with increase pressure.



**Figure .** Plot exhibiting (a) absolute value of the inverse temperature  $T_{inv}$  and (b) its ratio to the transition temperature  $T_{SmA-SmC^*}$  varying linearly with pressure. The solid line in both cases represents fit to a straight line.

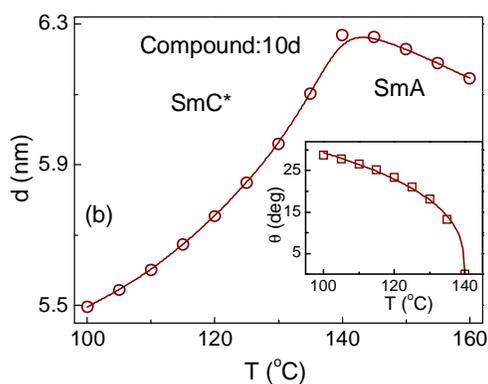
This work was carried out in collaboration with Jawad Naciri and B.R. Ratna from Naval Research Laboratory, Center of Bio/Molecular Science and Engineering, 4555 Overlook Avenue, Washington D.C. 20375, United States. This work is published: Prasad N. Bapat, D. S. Shankar Rao, S. Krishna Prasad, Jawad Naciri, and B.R. Ratna, *J. Phys. Chem. B*, **115**, 10425–10430 (2011).

**Investigators: D.S Shankar Rao, Prasad N. Bapat and S.Krishna Prasad**

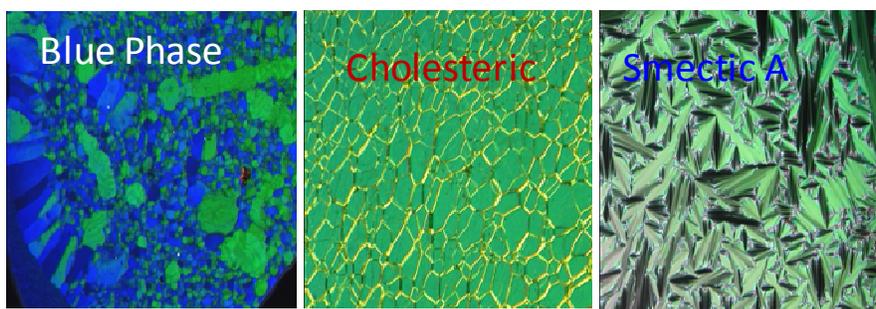
## **6.9 XRAY DIFFRACTION STUDIES ON UNSYMMETRICAL LIQUID CRYSTALLINE DIMERS**

Physical properties of unsymmetrical cholesterol and benzoxazole based liquid crystalline dimers have been carried out using polarized optical microscopy and Xray diffractometer

studies. The compounds exhibit blue phase, cholesteric, smectic A (Sm A) and smectic C\*(Sm C\*) phase sequence. Tilt angle in the Sm C\* is extracted and is fitted to a powerlaw expression. The SmA-Sm C\* transition is found to be more close to XY universality class as against that of a mean field behaviour based on the tilt angle exponent  $\beta$ .



**Figure :** Thermal variation of the layer spacing  $d$  across the SmA–SmC\* transition for a representative compound. Inset shows temperature dependence of the tilt angle  $\vartheta$ . Solid line is fit to the power law expression.



**Figure :** Representative textures shown by the compounds

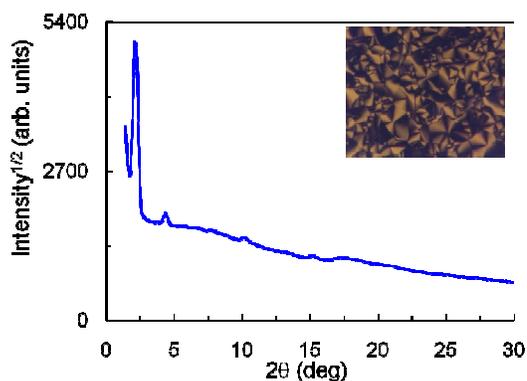
This work is carried out in collaboration with K.C. Majumdar and T. Ghosh from Department of Chemistry, University of Kalyani, Kalyani-741235, West Bengal, India. This work is published: K.C. Majumdar, T. Ghosh, D.S. Shankar Rao and S. Krishna Prasad, *Liq. Cryst.*, **38**, 1269–1277 (2011).

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

## **6.10 XRAY DIFFRACTION STUDIES ON OXOVANADIUM(IV) COMPLEXES**

The physical properties of new nondiscoid mononuclear oxovanadium (IV) complexes of tetradentate  $[N_2O_2]$  donor Schiff base has been carried out using Xray diffraction and

polarizing microscopic studies. The textural and Xray diffraction studies revealed that it is a columnar mesophase with 2D rectangular lattice with lattice dimensions of  $a=41.05 \text{ \AA}$  and  $b=20.23 \text{ \AA}$ .



**Figure:** Xray diffraction pattern for the representative compound. Inset shows the polarizing microscopic texture typical of the columnar mesophase.

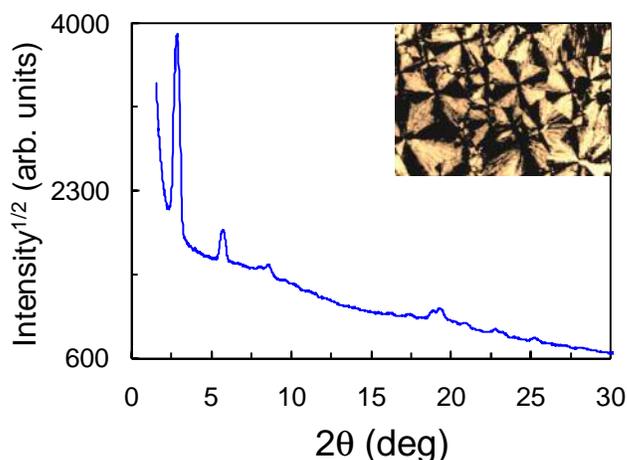
This work is carried out in collaboration with C. R. Bhattacharjee, Gobinda Das, P. Mondal of Department of chemistry, Assam University, Silchar 788011, Assam, India. This work is published: C. R. Bhattacharjee, Gobinda Das, P. Mondal, S. Krishna Prasad, D. S. Shankar Rao, *Inorganic Chemistry Communications*, **14**, 606–612 (2011).

**Investigators: D.S Shankar Rao, S.Krishna Prasad**

### **6.11 XRAY DIFFRACTION STUDIES IN HALF-DISC-SHAPED OXOVANADIUM(IV) COMPLEXES**

The mesomorphic behavior of non-disc-like oxovanadium(IV) Schiff base complexes have been investigated using optical polarizing microscopy studies and Xray diffraction measurements. The ligands were nonmesomorphic but their complexes exhibited a thermally stable enantiotropic highly ordered three-dimensional plastic mesophase with a columnar structure with a 2dimensional rectangular lattice, in the extended temperature range  $155-66^{\circ}\text{C}$ . To

account for the molecular arrangement a square pyramidal geometry for the vanadyl complexes has been proposed.

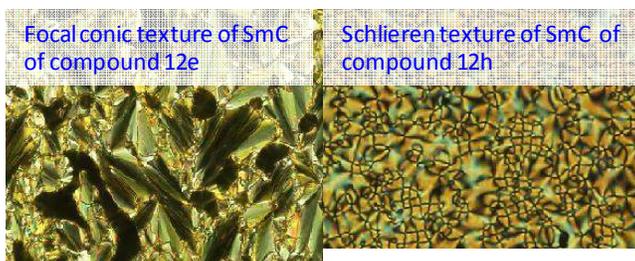


**Figure:** Xray diffraction pattern oxovanadium(IV) Schiff base. Inset shows the polarizing microscopic texture typical of the columnar mesophase.

This work is carried out in collaboration with C. R. Bhattacharjee, Gobinda Das, P. Mondal of Department of chemistry, Assam University, Silchar 788011, Assam, India. This work is published : C.R. Bhattacharjee, Gobinda Das, Paritosh Mondal, S. Krishna Prasad, D. S. Shankar Rao, *Liq. Cryst.*, **38**, 615 – 623 (2011).

**Investigators: D.S Shankar Rao, S.Krishna Prasad**

## **6.12 XRAY DIFFRACTION STUDIES IN PHENYLBENZOXAZOLE-CONTAINING CALAMITIC LIQUID CRYSTALS**



The liquid crystalline behavior of 2-phenylbenzoxazole liquid crystals having intramolecular hydrogen-bonded Schiff's base linkers is investigated using Polarizing optical

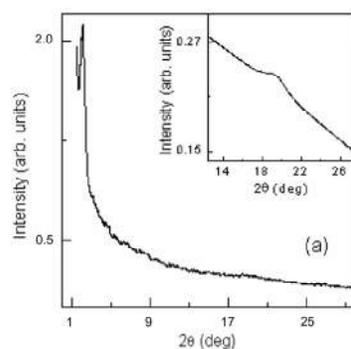
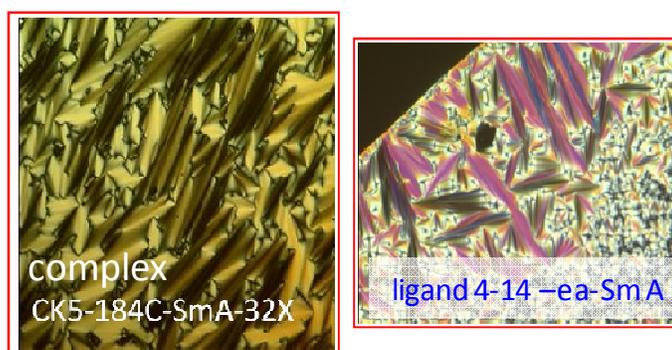
microscopy and Xray diffraction studies. They showed only SmC phase, the phase is stabilised over a wide temperature. Due to the presence of intramolecular H-bonding, the stability of the SmC phase is greatly enhanced.

This work is carried out in collaboration K.C. Majumdar , T. Ghosh from Department of Chemistry, University of Kalyani, Kalyani-741235, West Bengal, India. This work is published : K.C. Majumdar, T. Ghosh, D.S. Shankar Rao and S. Krishna Prasad, *Liq.Cryst.*, **38**, 625–632 (2011).

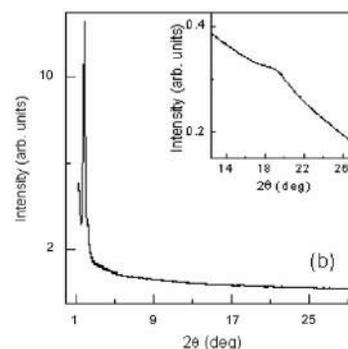
**Investigators: D.S Shankar Rao, S.Krishna Prasad**

### **6.13 XRAY DIFFRACTION STUDIES IN NOVEL PHOTOLUMINESCENT LANTHANIDOMESOGENS**

The liquid crystalline behavior of mononuclear lanthanide(III)-salicylaldehyde complexes has been investigated using polarizing optical microscopy and X-ray diffraction measurements. The ligands showed monotropic smectic A phase whereas the complexes exhibit enantiotropic highly viscous smectic A (SmA) mesophase in the temperature range 60–185°C. A bilayer self organized assembly of the molecules in the mesophase are proposed on the basis of the small angle XRD study.



**Figure 1:** X-ray diffractogram of the ligand at 74°C (The inset shows the wide angle diffuse peak on an enlarged scale).



**Figure 2:** X-ray diffractogram of the complex Pr-14-ea at 155 °C (The inset shows the wide angle diffuse peak on an enlarged scale).

This work is carried out in collaboration with C. R. Bhattacharjee, Gobinda Das, P. Mondal and P. Goswami of Department of chemistry, Assam University, Silchar 788011, Assam, India. This work is published: C. R. Bhattacharjee, Gobinda Das, P. Goswami, P. Mondal, S. Krishna Prasad, D.S. Shankar Rao, *Polyhedron* **30**, 1040-1047 (2011).

**Investigators: D.S Shankar Rao, S.Krishna Prasad**

#### **6.14 PHASMIDIC LIQUID CRYSTALS**

##### **NMR study:**

The phasmidic structure has been considered as a strong candidate for forming the elusive thermotropic biaxial nematic phase. To elucidate more into this subject we synthesised several series of phasmidic compounds using both conventional and non-conventional approaches. We found that these compounds behave in a unique way as their properties are concerned: for example, the mono-domain XRD pattern of these compounds show the small and wide angle reflections in the same direction and are perpendicular to the applied magnetic field. Also, more surprisingly, the d value obtained from the small angle region corresponds to only half the length of actual molecule. Therefore to find out whether the molecules exist as a monomer or a dimer in the mesophases of these compounds, we conducted a NMR study of a representative compound namely, TDPABA. The Carbon-13 NMR measurements of the chemical shifts as a function of temperature, indicate a dimer structure in the solution and suggest a similar structure in the nematic phase as well. The nematic order parameter  $S_{zz}$  is found to be relatively higher than that found in a typical calamitic liquid crystal, likely due to its underlying columnar phase

This work is carried out in collaboration with A. Marini and M.Geppi, Universita di Pisa, Pisa, Italy, and R.Y.dong, University of British Columbia, Canada. This work is published : NMR

study of a phasid-like liquid crystal, A. Marini, M. Geppi, Veena Prasad and R.Y. Dong, *Chemical Physics Letters*, **507**, 96-99, (2011).

**Investigator: Veena Prasad**

### **6.15 DISCOTIC LIQUID CRYSTALS**

**a. Anthraquinones** have been found to be very important components in various applications, such as those in the dye industry. Also, the quinonoid system here may behave as an electron acceptor and therefore, the system can be doped with electron donors to prepare *n*-type conductors. As a continuation of our investigations on the structure-property relationship of this core, we designed and synthesised several new monomers and dimers. The chemical structures of these compounds are established by means of organic spectroscopic methods. The liquid crystalline properties are investigated using polarising optical microscopy, differential scanning calorimetry and X-ray diffraction studies. They exhibit a variety of mesophases, viz., Col<sub>h</sub>, D<sub>L</sub> etc. We propose a molecular model in the discotic lamellar phase of one of the dimer compounds, based on the X-ray data obtained.

This work is carried out in collaboration with Arun Roy, Raman Research Institute, Bangalore. This work is published : Anthraquinone-based discotic liquid crystals: New monomers and dimers, Veena Prasad, Arun Roy, N.G. Naganeni and K. Gayathri, *Liq. Cryst.*, **38**, 1301-1314 (2011).

**Investigators: Veena Prasad, N.G. Nagaveni and K. Gayathri.**

**b. Polyalkynylbenzene (PAB)** based discotic compounds are found to be conducive to nematic mesophases. In the present investigation, we were interested in exercising the molecular engineering of PAB to form columnar mesophases. Thus, we designed and synthesised new molecules based on this core, having ether, thioether or sulfane or ester functional group. The

structure – property relationship of these PAB compounds, with respect to functional groups and peripheral aliphatic chains are also investigated.

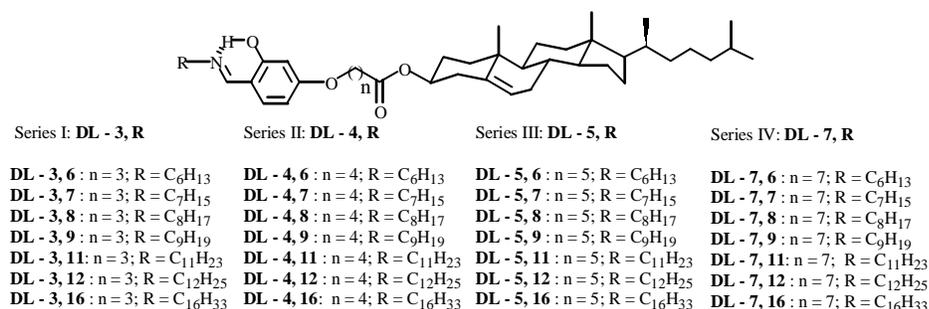
This work is carried out in collaboration with H. Nagayama and H. Takezoe, Tokyo Institute of Technology, Tokyo, Japan. This work is published : Room temperature columnar phase: Influence of 2-ethylhexane peripheral chain on the mesomorphism of polyalkynylbenzene based disc – shaped molecules, Sanjay K. Varshney, H. Nagayama, Veena Prasad and H. Takezoe, *Liq. Cryst.*, **38**, 1321-1329 (2011).

**Investigators: Veena Prasad and Sanjay K. Varshney**

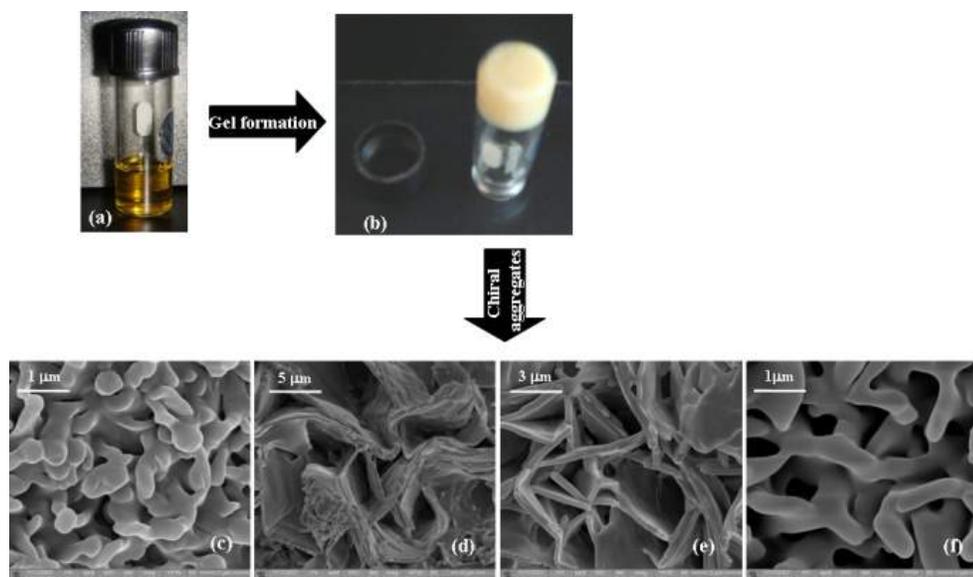
### **6.16 SYNTHESIS AND CHARACTERIZATION OF DIMER-LIKE OPTICALLY ACTIVE LIQUID CRYSTALS**

We have demonstrated that the thermal behavior and other functional characteristics of a relatively new class of liquid crystals, called dimer-like mesogens, is similar to that of liquid crystal dimers. They are made by covalently tethering cholesterol with salicylideneamine core through an  $\omega$ -oxyalkanoyloxy spacer of varying length and parity (Chart). Four series of compounds prepared primarily differ in the number of carbon atoms (length and parity) of the spacer. With a few exceptions in series having odd-parity spacer, all the compounds exhibit enantiotropic mesomorphism. In all the three even-parity spacer series, the variation in the length of the terminal tail influences the thermal property. A dramatic odd-even effect in the clearing temperatures occurs wherein the even-parity dimers possess higher values. Thus, the thermal behavior of these dimer-like compounds is analogous to that of liquid crystal dimers. The redox behavior of some representative samples has been probed by cyclic voltammetric (CV) experiment and the energy gaps are estimated by both CV and UV experiments. The results of these measurements are comparable, which emphasize that they genuinely possess

electrochemical activity. Notably, these compounds have tendency to form stable organic gel in ethanol where the gelators self-assemble into chiral aggregates with different morphologies of micrometer size.



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



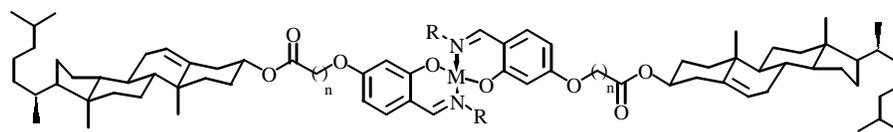
**Figure :** (a) Vial comprising a hot clear solution of one of the dimer-like compounds in 2% (w/v) ethanol. (b) Vial is inverted to show the formation of stable gel at room temperature. Also shown are the SEM images (c) - (e) of gel in 2% ethanol having different morphologies of micrometer size.

This work is published: G. Shanker and C. V. Yelamaggad. Synthesis and Phase Transitional Behavior of Dimer-Like Optically Active Liquid Crystals. *J. Phy. Chem. B*, **115**, 10849 (2011).

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

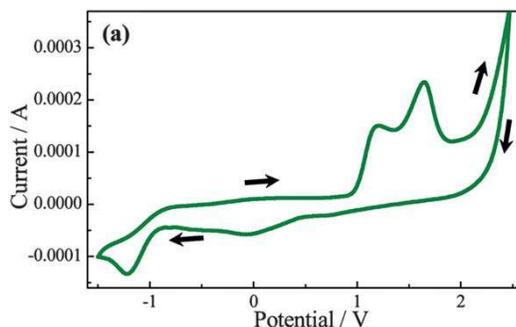
## 6.17 A NEW CLASS OF LOW MOLAR MASS CHIRAL METALLOMESOGENS: SYNTHESIS AND CHARACTERIZATION

We have evaluated the thermal behaviour of a new class of low molar mass chiral metallomesogens derived from cholesterol-based *N*-(*n*-alkyl)salicylideneamines (Chart). They exhibit monotropic chiral nematic (N\*) and smectic A\* (SmA\*) phases. Copper complex with a wide range of N\* phase metallomesogen was investigated for chiro-optical property by Circular Dichroism (CD) spectropolarimeter. Electrical parameters like ionisation potential (IP) and electron affinity (EA) were estimated by cyclic voltammetry (CV) experiments, which enabled us to understand the redox behaviour of these metallomesogens. The energy gap (DE) between the highest occupied molecular orbital (HOMO) and lowest unoccupied molecular orbital (LUMO) estimated by both CV (Figure) and UV experiments are comparable, which implies that these complexes possess electrochemical activity.



CL-M-n,R : n = 3, 4, 5 and 7; R = *n*-C<sub>6</sub>H<sub>13</sub> to C<sub>12</sub>H<sub>25</sub> and *n*-C<sub>16</sub>H<sub>33</sub>; M = Cu and Pd

**Chart:** Molecular structure of metallomesogens derived from dimer-like ligands



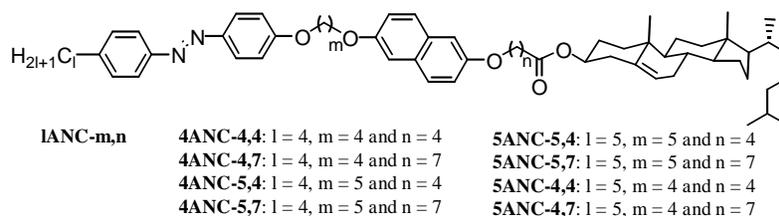
**Figure :** Cyclic voltammogram obtained for one of the palladium complexes at scan rate of 100 mV s<sup>-1</sup>

This work is published: G. Shanker and C. V. Yelamaggad. A new class of low molar mass chiral metallomesogens: synthesis and characterization. *J. Mater. Chem.*, 21, 15279 (2011).

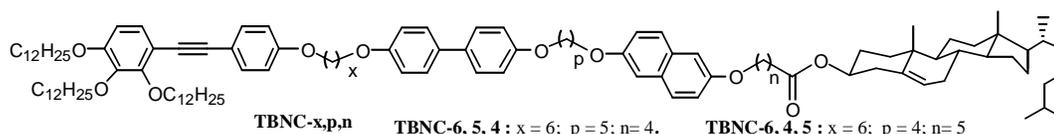
**Investigators: C. V. Yelamaggad and G. Shanker**

### 6.18 SYNTHESIS AND MESOMORPHISM OF NONSYMMETRIC TRIMERS AND TETRAMERS DERIVED FROM CHOLESTEROL

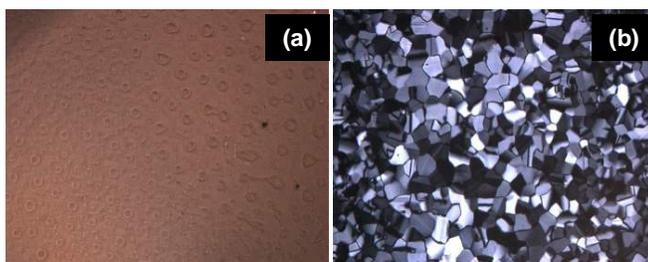
The phase transitional behavior of linear nonsymmetric trimers (Chart A) and tetramers (Chart B) has been established. Linear trimers have been made by covalently binding three different functional anisometric segments viz., promesogenic-optimally active-cholesterol, promesogenic-naphthalene and photochromic-azobenzene cores, through two flexible spacers of varying length and parity. Tetramers have been synthesized by linking cholesterol, naphthalene, biphenyl (a promesogenic) and tolane (a half-disc) mesogenic moieties via three flexible spacers. The occurrence of mesomorphism in these supermolecules has been evidenced by optical textural pattern (Figure), calorimetric and powder X-ray diffraction studies. The phase transitional behavior of these compounds has been compared with closely related known trimers and tetramers, which have served as reference / model for the substances synthesized in this study.



**Chart A** : Molecular structure of trimers derived from cholesterol



**Chart B** : Molecular structure of tetramers derived from cholesterol



**Figure :** Photomicrographs of pseudoisotropic texture of unknown mesophase obtained for one of the trimers (a) and mosaic texture of another trimer on cooling from isotropic state (b).

This work is published: A. S. Achalkumar, Uma S. Hiremath, D. S. S. Rao and C. V. Yelamaggad.

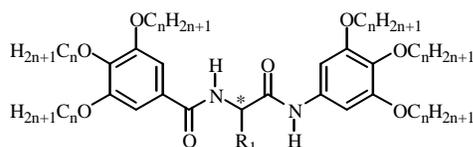
Nonconventional liquid crystals: synthesis and mesomorphism of nonsymmetric trimers and tetramers derived from cholesterol. *Liq. Cryst.*, **38**, 1563 (2011).

**Investigators: C.V.Yelamaggad, A.S.Achalkumar, Uma S. Hiremath and D.S.S.Rao**

### **6.19 SYNTHESIS AND CHARACTERIZATION OF CHIRAL HEXACATENAR-BISAMIDE LIQUID CRYSTALS**

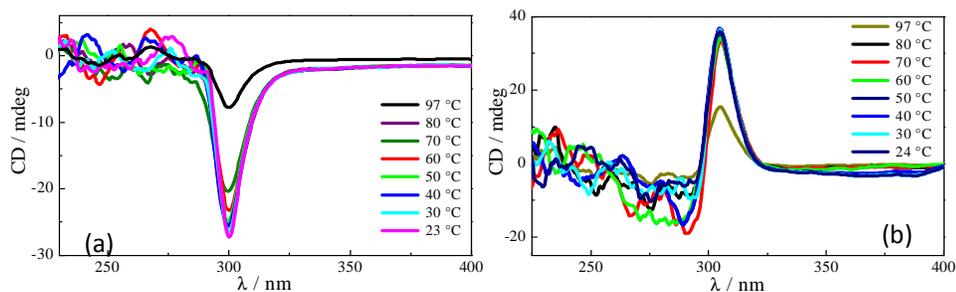
Novel hexacatenar bisamides consisting of **L-/D-leucine**, **L-/D-valine** or **L-alanine** as chiral spacers incorporated between two taper-shaped lipophilic segments (Chart), have been characterized. All compounds display enantiotropic columnar behavior; notably, in **L-alanine** substituted compound with decyloxy chain show the columnar phase over wide thermal range through the room temperature. X-ray diffraction studies carried on some representative samples revealed the rectangular symmetry. These compounds readily form stable chiral gels in ethanol. The existence of strong intermolecular hydrogen bonding is evidenced in both columnar and gel states by IR spectroscopy. The handedness of the Col phases and the gel was revealed by CD measurements. These bisamides have much lower clearing temperature when compared to the homomeric dipeptides. Further developments are necessary in this kind of

bisamides to induce polarity in the columnar structure and also for usage as components for room temperature Col mixtures. Super cooled helical Col phases observed in these materials makes them promising for many applications due to their responsiveness towards external stimuli.



**HBA - 1 to HBA - 10** :  $R_1 = (S)$ -Methyl ;  $(S/R)$ -Isobutyl;  $(S/R)$ -Isopropyl;  $n = 10 / 12$

**Chart** : Molecular structure of optically active hexacatenar-amides



**Figure**: CD spectra recorded as a function of temperature in the Col phase of enantiomers

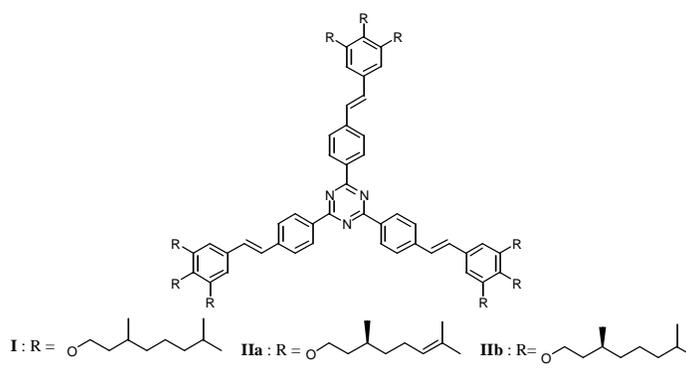
This work is published: G. Shanker, D. S. Shankar Rao, S. Krishna Prasad and C. V. Yelamaggad. Self-Assembly of Chiral Hexacatenar-Bisamides into Columnar Structure, *RSC Advances*, **2**, 1592 (2012).

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

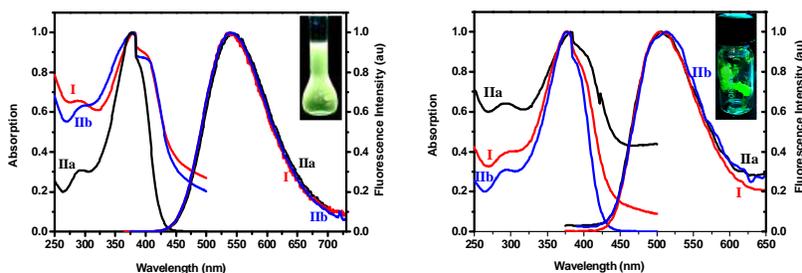
## 6.20 LUMINESCENT COLUMNAR LIQUID CRYSTALS DERIVED FROM S-TRIAZINE CORE: SYNTHESIS AND CHARACTERIZATION

Novel achiral / chiral star-shaped liquid crystals (LCs) (Chart), in which three fluorophore arms such as 1,2,3-tris(alkoxy)-5-styrylbenzenes are tethered to a central s-triazine core, have been prepared by three fold Horner-Wadsworth-Emmons (HWE) reaction of triphosphonate with

achiral / chiral 3,4,5-tris(alkoxy)benzaldehydes. These star-shaped liquid crystals, display columnar liquid crystalline phase over a wide temperature range existing between well below and above the room temperature, which is evidenced by optical and calorimetric studies. Besides, they show photoluminescence both in solution and mesomorphic states (Figure). Thus, given their self-organization into fluid one-dimensional columnar array coupled with light generating capability, these organic ordered-fluids can be regarded as novel media for advanced technological applications.



*Chart : Molecular structure of star-shaped discotics derived from s-triazine core*



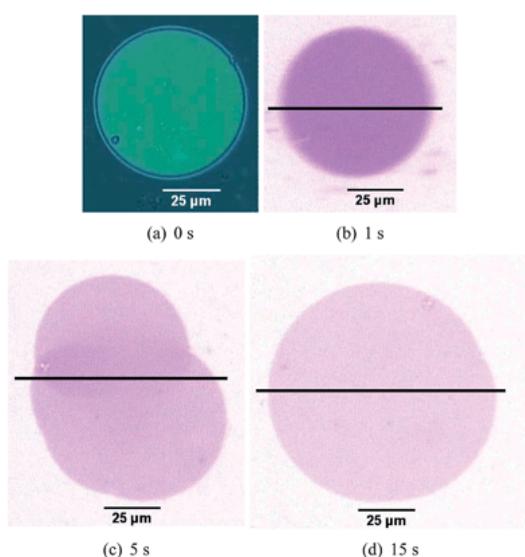
**Figure :** UV-Vis absorption (left regions) and emission (right portions) spectra of all the three discotics in their solution (LHS panel) and mesomorphic (RHS panel) states. Insets in both the panels show the pictures of solution and Col states respectively, as seen after the illumination of the light of 354 nm.

This work is published: Hashambi K. Dambal and C. V. Yelamaggad. Technologically promising, room temperature luminescent columnar liquid crystals derived from s-triazine core: molecular design, synthesis and characterization. *Tetrahedron Lett.* **53**, 186 (2012).

**Investigators: C. V. Yelamaggad and Hashambi K. Dambal**

## 6.21 SPREADING AND RETRACTION DYNAMICS OF A DYE DOPED SMECTIC LIQUID CRYSTAL DOMAIN AT THE AIR–WATER INTERFACE

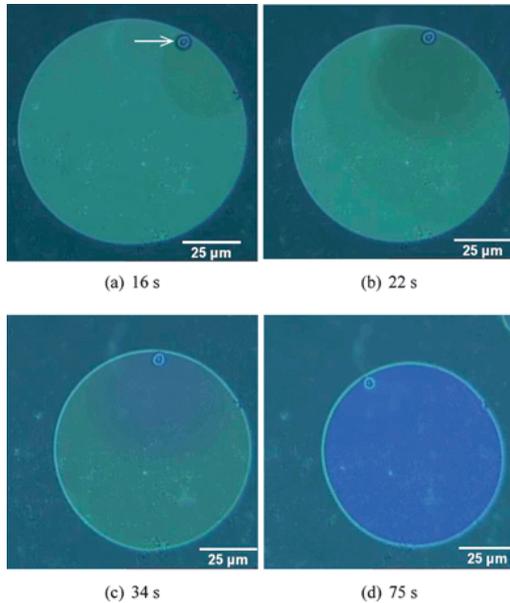
Spreading of a liquid drop over a liquid subphase has drawn wide attention due to its importance in oil recovery, spillage, foam and emulsion stability. There are few reports in the literature addressing the spreading and retraction dynamics in isotropic drops where evaporation, diffusion and reaction at interfaces play an important role leading to such dynamics. However, there exist no such reports for the case of droplets in the liquid crystalline phase in equilibrium with a thin background film.



**Figure 1:** Dye doped smectic domain at the air–water interface. (a) Under reflection, (b–d) Spontaneous spreading of the domain is seen under fluorescence (contrast inverted).

We have studied the spreading and retraction dynamics in 4'-octyl-4-biphenylcarbonitrile (8CB) doped with 1% molar concentration of a fluorescent dye (4-(hexadecylamino)-7-nitrobenz-2-oxa-1,3-diazole) in the collapsed state of a Langmuir monolayer at the air–water interface. We employed a microscope with a provision to view the isolated domain in the smectic phase either in the reflection or epi-fluorescence settings. We find that the domain undergoes shearing when excited with an appropriate wavelength in the epi-fluorescence setting of the microscope and results in spreading asymmetrically at the interface (Fig. 1).

Eventually, due to line tension, the domain transforms into a circular shape. Here, the domain area was about twice that of the initial area. Under reflection setting of the microscope, with white light, we observe retraction of the domain to a smaller area (Fig. 2). During the course of retraction, we find successive generation and evolution of edge dislocation loops leading to thickening of the domain.



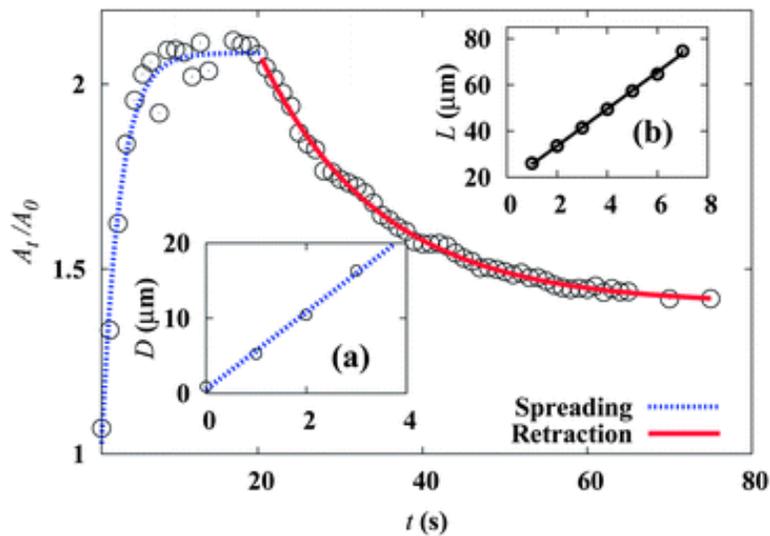
**Figure 2:** Retraction of the smectic domain at the air-water interface in reflection setting of the microscope. Changes in the interference color indicate a change in thickness. Edge dislocation loops generated from a seed (indicated by an arrow in (a)) are seen during retraction of the domain.

Our analysis on the variation of the normalized area of the domain with time (Fig. 3) yields different characteristic time constants for spreading (faster) and retraction (slower). The velocity of the front during shearing is found to be  $5.2 \mu\text{m/s}$  (inset a of Fig.3). The velocity of the edge dislocation loop is found to be  $8 \mu\text{m/s}$  (inset b of Fig. 3).

The thickness of the domain is estimated from imaging ellipsometry and found to be in the range of 50 to 70 nm (Fig. 4).

The spreading and retraction of the domain can be understood by invoking changes in interfacial tension which changes the sign of the spreading coefficient. This is due to the

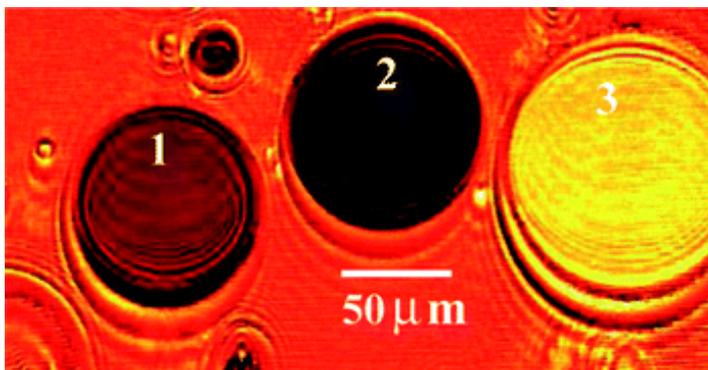
presence of surface active agents formed during photo-bleaching causing spreading and subsequent depletion of the photo-bleached products causing retraction of the domain.



**Figure 3:** Variation of the normalized area of the smectic domain during spreading ( $t < 15$  s) and retraction ( $t > 15$  s). Inset (a) shows the displacement of the sheared front with time during spreading. Inset (b) shows the displacement of the loop with time during retraction.

These studies are of relevance to liquid crystal emulsions and dispersions. Also the dynamics of the domain mimics the spreading of the pulmonary lung surfactant over a thick mucous layer.

This work is carried out in collaboration with Bharat Kumar of Raman Research Institute.

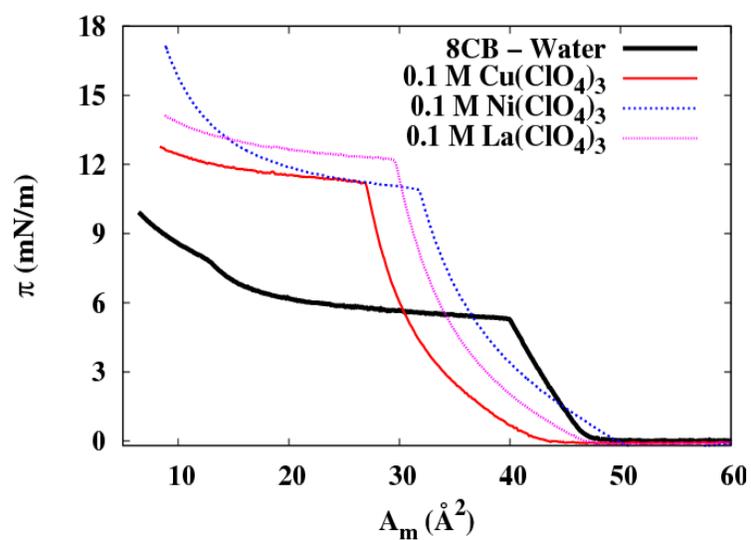


**Figure 4:** Phase shift map of the coexisting smectic domains of different thicknesses (label 1: 69.3nm, 2: 74.8 nm and 3: 44.2 nm) obtained under imaging ellipsometer. Different colors indicate different phase shifts.

**Investigators: P. Viswanath and K. A. Suresh**

## 6.22 INFLUENCE OF MULTIVALENT CATIONS ON MESOGENIC AMPHIPHILIC MOLECULES AT THE AIR-WATER INTERFACE

Understanding the orientational and anchoring transitions in liquid crystal is important in the context of chemical and bio sensor applications. Molecular recognition and self assembly play a vital role in such transitions. The orientational response of the liquid crystal changes when exposed to analytes. This transition results in a drastic change in the macroscopic optical response. Recently, such an orientational response has been observed in nematic liquid crystal over salt surfaces. Interfaces play a major role in these cases and triggers such events. However, it is not clear to what extent the ions influence the structure and packing of the liquid crystal causing this transition. We have investigated the liquid crystal, 4-octyl-4'-



**Figure :** Surface pressure-area/molecule isotherm for 8CB monolayer with divalent and trivalent ions in the subphase.

biphenyl carbonitrile (8CB) with multivalent ions at air-water interface. Using surface manometry ( $\pi - A_m$  isotherm), we found that the ionic interaction leads to condensation in the area per molecule and increases the value of collapse pressure as shown in Figure. This indicates that the presence of ions enhances the stability of the monolayer at the air-water

interface. There is moderate change in the magnitude of their elastic modulus. Further investigations are in progress.

**Investigators : P. Viswanath and T. Shilpa Harish**

### ***6.23 DETECTION AND DYNAMICS OF EDGE DISLOCATIONS IN THE ELECTROCONVECTION IN PLANE ROLL STRUCTURE OF A BENT CORE NEMATIC***

During anisotropic electro-convection in nematic liquid crystals, as a result of wavevector mismatch, edge dislocations are formed in the patterned state. At the core of such defects, the amplitude goes to zero and the phase is undefined. If the amplitude field is slowly varying, it is possible to locate the defect position using complex zero crossing method; this procedure has been applied for the analysis of defects in the conventional Williams roll structure. In an attempt to extend this technique to 'nonstandard' inplane rolls of a bent core nematic, we have developed a code, which does a smoothing (Gaussian kernel) on the 2D image containing the defect. The image is 2D Fourier transformed and the complex conjugate is set to zero along with the DC component. Further, the higher harmonics in the Fourier domain are set to zero. To remove the underlying periodicity, a shifting of the dominant peak to zero frequency is performed. This is followed by inverse Fourier transform which yields a complex field. The defect location is identified by the crossing of contours of real and imaginary parts. Analysis of the position and dynamics of defects is essential to understand the nature of inter-defect interaction.

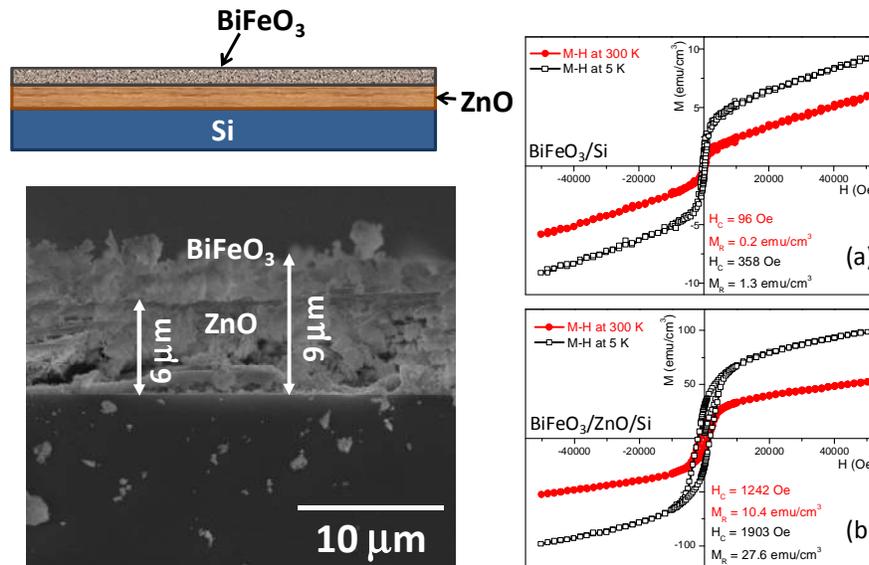
**Investigators : P.Viswanath, K.S. Krishnamurthy and Pramod Tadapatri**

## **6.24 ENHANCED MAGNETIC PROPERTIES OF CHEMICAL SOLUTION DEPOSITED $\text{BiFeO}_3$ THIN FILM WITH $\text{ZnO}$ BUFFER LAYER**

Among the multiferroics, bismuth ferrite,  $\text{BiFeO}_3$ , has attracted much attention, because it is one of the well known multiferroic materials at room temperature and has giant spontaneous polarization, which offers potential applications in information storage, such as new generation spintronic devices and sensors. However,  $\text{BiFeO}_3$  has got issues like, small magnetization and weak magnetoelectric coupling. The weak ferromagnetism observed in  $\text{BiFeO}_3$  results from the canting of antiferromagnetic Fe sublattice. Hence, for  $\text{BiFeO}_3$  to be exploited in device applications, it is essential that its magnetic properties should be improved, in order to get a better magnetoelectric coupling. In this study, we have used  $\text{ZnO}$  as buffer layer to increase the magnetization of  $\text{BiFeO}_3$  film.

We have studied magnetic properties of  $\text{BiFeO}_3$  films deposited on Si substrates with and without  $\text{ZnO}$  buffer layer. We adopted the chemical solution deposition method for the deposition of  $\text{BiFeO}_3$  as well as  $\text{ZnO}$  films. The x-ray diffraction measurements on the deposited films confirm the formation of crystalline phase of  $\text{BiFeO}_3$  and  $\text{ZnO}$  films, while our electron microscopy measurements help to understand the morphology of few micrometers thick films. It is found that the deposited  $\text{ZnO}$  film exhibit a hexagonal particulate surface morphology, whereas  $\text{BiFeO}_3$  film fully covers the  $\text{ZnO}$  surface. Our magnetic measurements reveal that the magnetization of  $\text{BiFeO}_3$  increases by more than ten times in  $\text{BiFeO}_3/\text{ZnO}/\text{Si}$  film compared to  $\text{BiFeO}_3/\text{Si}$  film, indicating the major role played by  $\text{ZnO}$  buffer layer in enhancing the magnetic properties of  $\text{BiFeO}_3$ , a technologically important multiferroic material. This enhancement in ferromagnetism is possibly arising from the nanostructured  $\text{ZnO}$  buffer surface induced nano-sized polycrystalline grains of  $\text{BiFeO}_3$  film, which destroys the antiferromagnetic spiral spin structure. The enhancement in the magnetization of  $\text{BiFeO}_3$  due

to ZnO buffer layer is important because it can help to improve the magnetoelectric coupling for utilizing the room temperature multiferroicity of BiFeO<sub>3</sub> for practical applications.



**Figure:** Schematic and SEM cross-section image of BiFeO<sub>3</sub>/ZnO/Si film (left). Magnetization versus magnetic field data of the films (right). The figure (b) shows 10 times enhanced magnetization compared to (a).

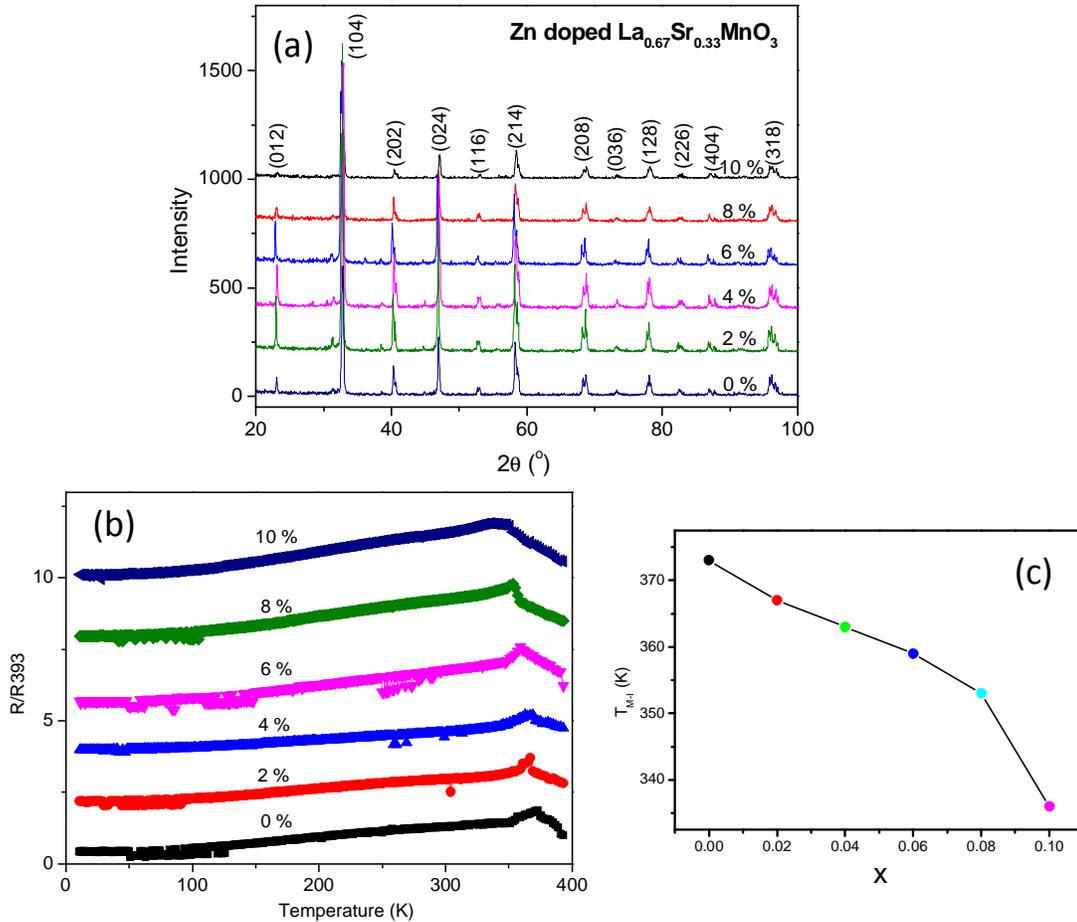
This work has been accepted for publication in Materials Science and Engineering B (2012).

**Investigators :** S. Angappane, R. Rajalakshmi and Nagaiah Kambhala

### 6.25 STRUCTURAL, MAGNETIC AND MAGNETOTRANSPORT BEHAVIOUR OF ZnO DOPED La<sub>0.67</sub>Sr<sub>0.33</sub>MnO<sub>3</sub> COMPOUNDS

Strontium doped lanthanum manganite, La<sub>0.67</sub>Sr<sub>0.33</sub>MnO<sub>3</sub> (LSMO) is one of the colossal magnetoresistance (CMR) materials that have attracted intensive research interests on account of their CMR and spin-dependent tunneling properties, which make them attractive candidate for high performance magnetic devices. The effect of Mn-site doping on physical properties of colossal magnetoresistance (CMR) manganites is very important because it directly affects double exchange effect by modifying the Mn<sup>3+</sup>-Mn<sup>4+</sup> network. We studied the

polycrystalline  $\text{La}_{0.67}\text{Sr}_{0.33}\text{Mn}_{1-x}\text{Zn}_x\text{O}_3$  ( $x=0, 0.02, 0.04, 0.06, 0.08, 0.1$ ) compounds prepared by solid state reaction of respective oxides.



**Figure:** (a) XRD data, (b) Resistance versus temperature after oxygen annealing with  $1000^\circ\text{C}$  for 48 hours and (c) variation of metal insulator transition temperature ( $T_{MI}$ ) with Zn doping concentration for  $\text{La}_{0.67}\text{Sr}_{0.33}\text{Mn}_{1-x}\text{Zn}_x\text{O}_3$  ( $x=0, 0.02, 0.04, 0.06, 0.08, 0.1$ )

Figure (a) shows the x-ray diffraction data of Zn doped  $\text{La}_{0.67}\text{Sr}_{0.33}\text{MnO}_3$  material, wherein all peaks belong to  $\text{La}_{0.67}\text{Sr}_{0.33}\text{MnO}_3$  material and showing perovskite structure with R-3c space group. There is no secondary phase observed. Due to the oxygen deficiency peak shift of doped and undoped  $\text{La}_{0.67}\text{Sr}_{0.33}\text{MnO}_3$  are random. Figure (b) show temperature dependence of resistance for Zn doped  $\text{La}_{0.67}\text{Sr}_{0.33}\text{MnO}_3$  samples from 12 to 393 K, measured by conventional

four probe method. A typical metal-insulator transition of a CMR oxide is observed in all samples: the resistance increases with increasing temperature till the peak temperature,  $T_{M-I}$ , called metal-insulator transition temperature and upon further increasing temperature the resistance decreases. Figure (c) shows that the metal-insulator transition temperature decreases with the increasing concentration of Zn doping. Such a dependence on Zn concentration shows that the increase in Zn doping results in destruction of double exchange interaction which lead to a decrease of the electrons' hopping along Mn-sites.

Further, the magnetic measurements have to be carried out in order to understand the magnetic state of these materials.

**Investigators : S. Angappane and Nagaiah Kambhala**

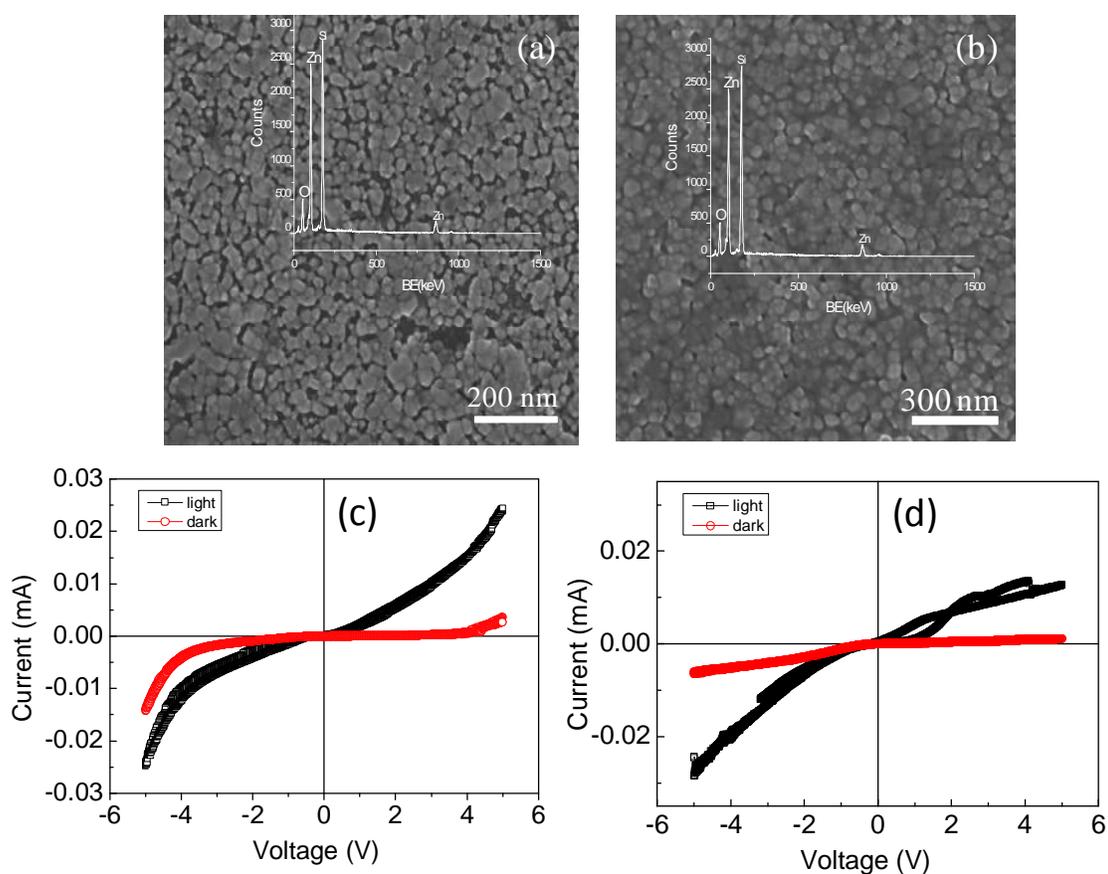
## **6.26 GROWTH OF ZnO THIN FILMS AND DEVICE FABRICATION**

In this work, photo sensing characteristics of metal-semiconductor-metal (MSM) device using ZnO was studied. In the MSM device, a large barrier height leads to small leakage current and high breakdown voltage, which could result in improved responsivity and photocurrent to dark current ratio. The zinc oxide thin films were deposited on Si (100) substrates by spin coating technique. The aqueous solution of 0.045 M of zinc acetate hydrate was spin coated on Si substrate at 8000 rpms for 60 s. Each layer is heated for 1 min on hot plate at 135°C after each successive deposition. This above step is repeated to obtain 10 and 20 coatings and finally the obtained films were annealed in a tube furnace under oxygen ambience for 1 hr at 600 °C.

The FESEM images of the of ZnO/Si film in figure 3(a,b) show the smooth and uniform distribution of grains with hexagonal facet morphology over the entire surface. The EDX analysis of the surface chemical species confirms the presence of Zn and O in the film addition

to Si from substrate. The average particle size was found to be 40 nm. The average thickness of ZnO films for 10 and 20 coating steps were found out to be 800 nm and 1000 nm respectively.

The current voltage ( $I$ - $V$ ) characteristics of the deposited thin films are shown in figure (c,d). The in-plane electrical contacts were made using silver paint. The  $I$ - $V$  plots, measured by sweeping voltage upto  $\pm 5$  V, show nonlinear behaviour. It is observed that when the sample was illuminated with an incandescent light (power of 60 watts), a photo induced current was generated due to the photo generated carriers. However, it is noted that in case of thin film of 1000 nm, the conductivity value is slightly lower than the film of thickness 800 nm.



**Figure:** SEM image and  $I$ - $V$  characteristics of ZnO/Si films of (a, c) 800 and (b,d) 1000 nm thickness respectively.

Thickness of ZnO/Si	$\frac{I(\text{light})}{I(\text{dark})}$
10 coatings (800 nm)	6.67
20 coatings (1000 nm)	11.6

**Table :** Photo-current ratio for two different thicknesses of ZnO thinfilms.

The dark current and photo-current ratio are found to be high for the 1000nm film. Further responsivity of these ZnO devices for different wavelengths are being studied.

**Investigators :** S. Angappane and R. Rajalakshmi

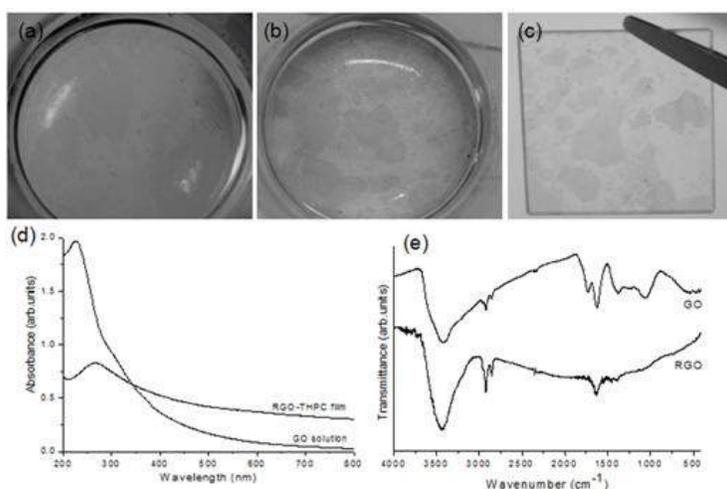
### **6.27 INVESTIGATION OF REDUCED GRAPHENE OXIDE THIN FILMS FORMED AT AIR-WATER INTERFACE AND DECORATION WITH NOBLE METAL NANOPARTICLES**

Graphene, a single layer of graphite, has emerged as a powerful platform for the future nanoelectronics due to high carrier mobility, ballistic transport and excellent mechanical and thermal properties. Since its demonstration as a potential quantum electronic device, the scientific literature is enriched with various strategies to produce graphene on a large scale without compromising on its quality. Among the several methods, chemical or thermal reduction of solution processed exfoliated single layer graphite oxide platelets is the popular method of producing graphene in laboratories owing to its inexpensive and simple methodology.

We have employed tetrakis(hydroxymethyl)phosphonium chloride (THPC) as the reducing agent to obtain large area, free-standing films of reduced graphene oxide (RGO) at air-water interface. When a dilute graphene oxide solution (GO) solution is heated at 100°C with small amounts of THPC, films continuous over cm scale containing folds and tiny black particles are

seen floating on the water surface within an hour (Fig.1a). A higher concentration of GO (>0.5 mg/mL) and THPC and longer reaction time (>3 hrs) causes more aggregation and forms thicker films (Fig.1b). The films are transferable to any substrates (Fig.1c). UV-Vis spectra (Figure 1d) acquired from the GO solution and the film after reaction with THPC reveal a red shift of the  $\pi$ - $\pi^*$  transition peak of C=C from 227 to 265 nm indicating reduction of GO and restoration of aromatic network. FT-IR spectra of GO and RGO (Fig.1e) show that majority of the oxygen functional groups such as epoxy ( $1060\text{ cm}^{-1}$ ), carbonyl ( $1730\text{ cm}^{-1}$ ), and carboxyl ( $1380\text{ cm}^{-1}$ ) groups have been removed by THPC reduction.

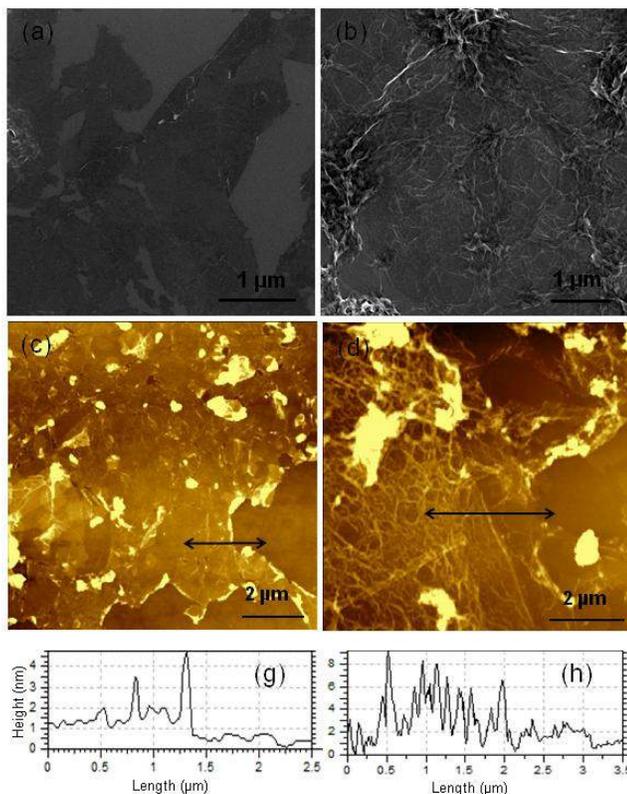
The surface morphology was studied by SEM and AFM (Fig. 2). SEM and AFM images show that the thin RGO film consists of tightly packed 1 nm graphene platelets (Figs. 2a, 2c). A thicker film contains a folded and wrinkled mass of graphene platelets placed one over the other and aggregated particles (Figs. 2b, 2d).



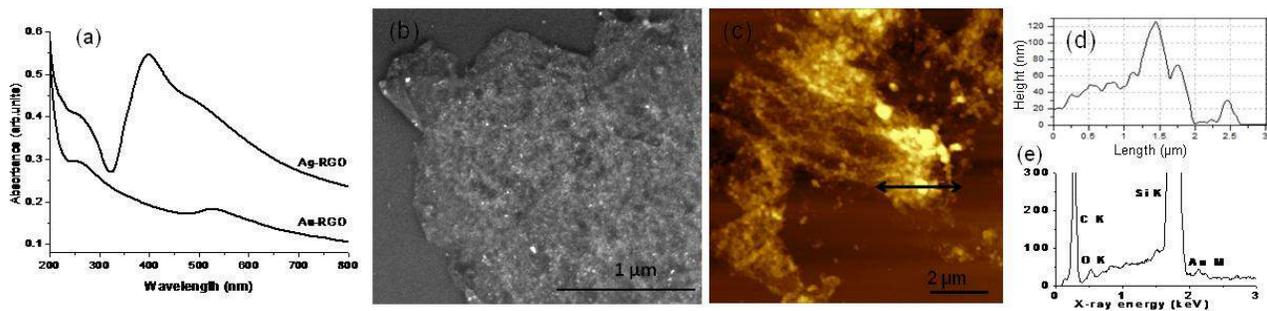
**Figure 1:** a) Photograph of a transparent thin RGO film floating on the water surface in a 100 mL beaker b) Photograph of a thicker RGO film on the water surface produced using a higher initial concentration of GO c) RGO film transferred to a  $2.5 \times 2.5\text{ cm}$  quartz substrate d) UV-Vis absorption spectra of GO solution and RGO film e) FT-IR spectra of GO and RGO.

A step further, we have employed THPC reducing agent to obtain RGO-metal NP composite films at air-water interface, in a rapid, one-step synthesis GO and metal salts such as  $\text{HAuCl}_4$  and  $\text{AgNO}_3$  were added to THPC in NaOH solution and heated. Patches of aggregated films are seen floating on the water surface. The surface plasmon absorptions in the UV-Vis spectra

confirm the presence of metal nanoparticles (Fig. 3a). The surface morphology of the RGO-metal nanoparticle films and the composition are obtained by AFM, SEM and energy dispersive spectra (EDS) (Figs. 3b, 3c). The method could also be applied to obtain RGO-Pd nanoparticle films.



**Figure 2:** a) High magnification SEM image of the thin RGO film b) SEM image of the thick film showing wrinkled portions and aggregated regions c) AFM topography of the thin RGO film acquired in intermittent contact mode d) AFM topography of the thick RGO film showing a cob-web pattern with single layer platelets at the edges g) Cross-section profile across the black line in (c) showing the thickness of thin regions to be 1 nm. h) Cross-section profile across the black line in (d) showing the thickness of film edges to be 1 nm and folded regions to be 10 nm.



**Figure 3 :** (a) UV-Vis spectra showing the plasmon absorption from RGO-Au nanoparticle and RGO-Ag nanoparticle suspensions (b) SEM image of RGO-Au nanoparticle film showing particles attached to RGO sheet c) AFM topography of the RGO-Au nanoparticle film d) Cross-section analysis across the black line in (c), (e) EDS spectra showing the presence of Au.

Further studies exploring the optical and electrical characteristics and the applications in catalysis are in progress.

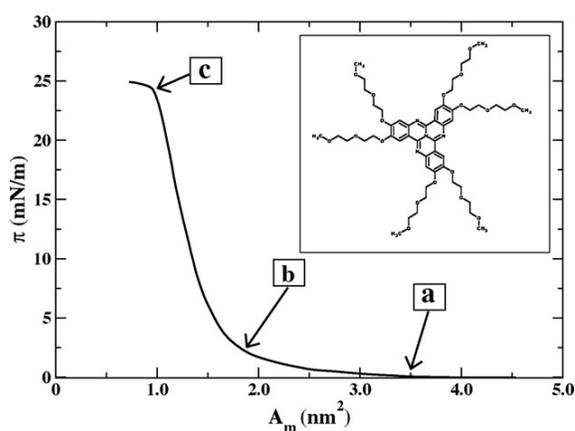
**Investigator : Neena S John, Bramhaiah Kommula**

### ***6.28 MONOLAYER FILMS OF TRICYCLOQUINAZOLINE CORE DISCOTIC MESOGENIC MOLECULES AT AIR-WATER AND AIR-SOLID INTERFACES***

Discotic mesogenic molecules can have unique molecular electronic properties like two dimensional delocalization of electrons which are not found in linear oligomers or in polymers. We have studied the monolayer films of amphiphilic hexakis[2-(2-methoxyethoxy)ethoxy] tricycloquinazoline (AmTCQ) discotic mesogenic molecules at the air-water and air-solid interfaces. The standard discotic molecules are rich in  $\Pi$ -electrons, and they are known to behave as a p-type semiconductor with appropriate doping. Interestingly, the tricycloquinazoline (TCQ) core discotic molecules are deficient in  $\Pi$ -electrons and are reported to behave as a n-doped semiconducting material. The chemical structure of the molecule is shown in the inset of Fig. 1. The AmTCQ molecules form a stable Langmuir monolayer at the air-water interface. We have employed surface manometry, Brewster angle microscopy and atomic force microscopy to study the various phases and structure of the monolayer. The surface pressure ( $\pi$ ) - area per molecule ( $A_m$ ) isotherm of AmTCQ molecules is shown in Fig. 1. The monolayer exhibits gas phase, low density liquid (L1) phase, and high density liquid (L12) phase.

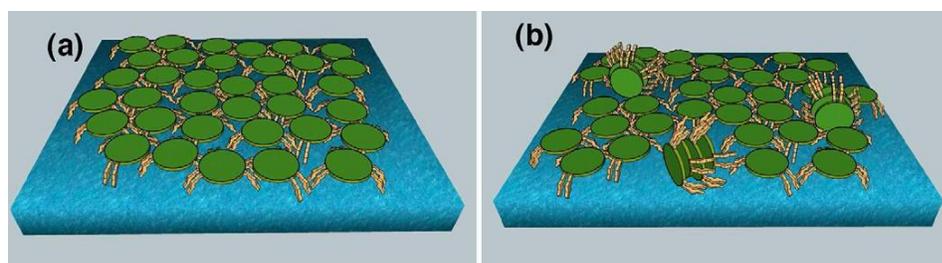
The intensity of the Brewster angle microscope (BAM) images depends on the thickness of the film and the surface density of the molecules. For the AmTCQ molecules, the limiting value ( $A_0$ ) in the L1 phase was  $3.3 \text{ nm}^2$ . The BAM images show a uniform gray texture in this phase. Hence, the molecules are more likely to be in the face-on conformation with interdigitated

side-chain in the L1 phase. The value of  $A_o$  in the L12 phase was found to be  $1.6 \text{ nm}^2$  which is large for the edge-on and small for the face-on conformation. The BAM images in this phase reveal the coexistence of bright and gray regions. The bright regions may correspond to the domains of the molecules with edge-on conformation, whereas the gray background may represent face-on conformation. The large value of  $A_o$  in the L12 phase is accounted by a coexistence of domains with face-on and edge-on conformations.



**Figure 1:** Surface pressure ( $\pi$ ) – area per molecule ( $A_m$ ) isotherm of the AmTCQ monolayer. The arrows a, b and c indicate the onset of low density liquid (L1), high density liquid (L12) phases and collapse state during compression. Inset shows chemical structure of the AmTCQ molecule.

Based on our results, we propose a model for the molecular orientation in different phases of Langmuir monolayer of AmTCQ molecule. This is shown in Fig. 2. Fig. 2(a) shows the face-on conformation of the disk-shaped molecules with the interdigitated side-chain in the L1 phase. Fig. 2(b) shows both face-on and edge-on conformations in the L12 phase.



**Figure 2:** A schematic depiction of AmTCQ molecules at the A-W interface. The molecular conformation in (a) L1 and (b) L12 phases.

The conformation of the discotic molecules on the surface depends on intermolecular and molecule–substrate interactions. If the intermolecular interaction is greater than the

molecule–substrate interaction, the molecules prefer the edge-on over the face-on conformation. The discotic molecules rich in  $\Pi$ -electrons have stronger core–core interaction leading to the condensed liquid state with edge-on conformation of the molecules. In our case, the molecules are deficient in  $\Pi$ -electrons resulting in weaker inter- molecular interaction. Such weak intermolecular interaction may be responsible for the L12 phase where the molecules exhibit a combination of edge- on and face-on conformations.

This work was carried out in collaboration with Raj Kumar Gupta and Sandeep Kumar of the Raman Research Institute, Bangalore. This work is published: R.K.Gupta, V.Manjuladevi, C.Karthik, Sandeep Kumar and K.A.Suresh, *Colloids and Surfaces A: Physicochem. Eng. Aspects*, **410**, 91 (2012)

**Investigator: K.A.Suresh**

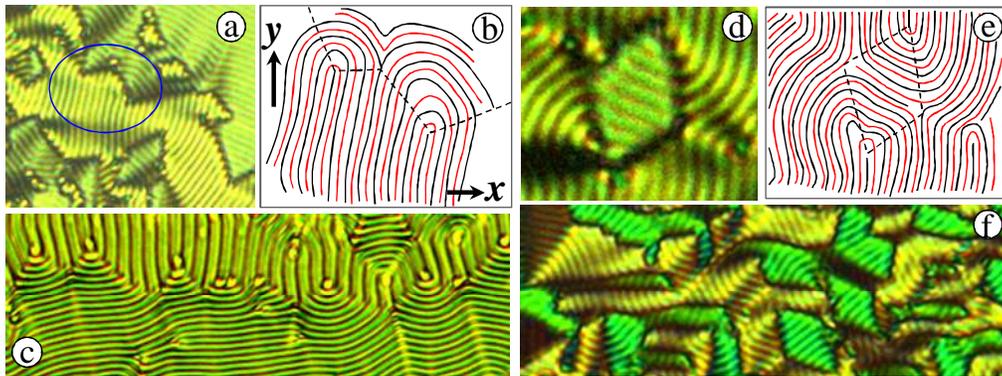
### **6.29 PATTERNED FLEXOELECTRIC INSTABILITY IN A BENT-CORE NEMATIC LIQUID CRYSTAL**

In this study, we examine the Bobylev-Pikin flexoelectric instability in an initially planar monodomain of a bent-core nematic liquid crystal, which is negative in conductivity and dielectric anisotropies. Experiments employing dc excitation reveal the domain density to be linear in field, as predicted; however, the instability threshold has a negative temperature coefficient indicating the effective flexomodulus as nonquadratic in order parameter. The dc threshold is also determined as a function of simultaneously acting ac voltage; a theoretical fit is found for the data taking into account elastic anisotropy, whereby the relevant flexoelectric and elastic parameters are estimated. Remarkable morphological changes occur under an increasing field. Half-strength disclinations of opposite topological charge evolve within the flexostructure rendering the wavevector orientation degenerate in the layer plane (Figure).

Dipolar and quadrupolar topological defect patterns, akin to the singularities in cholesteric fingerprint texture, lead finally to fan like objects. The morphological equivalence between the periodic flexoelectric state and a layered lattice as realized here is attributable to a much lower energy of bend type distortion compared to splay, unlike in a calamitic.

This work, which was carried out in collaboration with W. Weissflog, has been published:

Pramod Tadapatri, K. S. Krishnamurthy and W. Weissflog, *Soft Matter* **8**, 1202-1214 (2012).



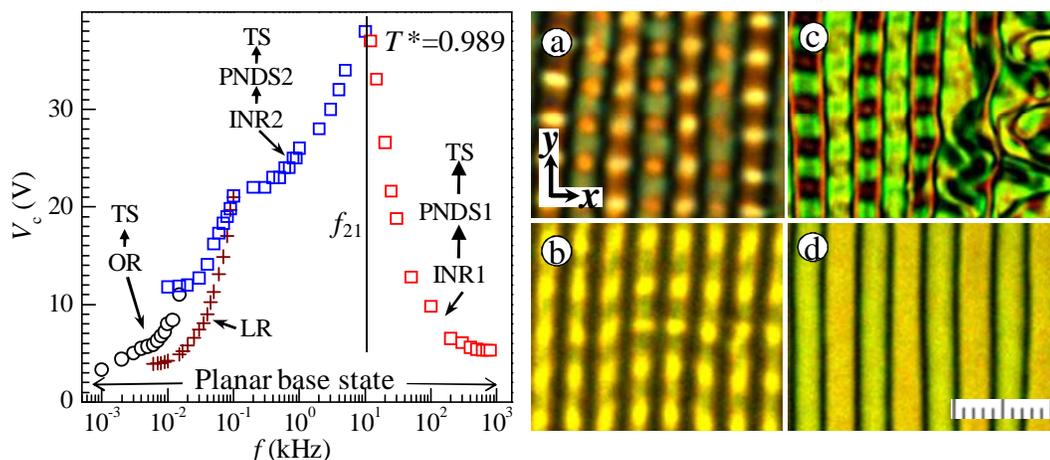
**Figure :** Various patterns formed by  $\tau^+$  and  $\tau^-$  disclinations in the flexodomain structure. (a) Zig-zag extinction lines seen under crossed polarizers; they join positive and negative defects occurring alternately at the turning points. (b) The director field corresponding to the encircled region in (a); the black and red lines are along the dark and bright bands of the pattern. (c) An array of alternately positive and negative  $\pi$ -disclinations as seen with a single polarizer along  $y$ . (d) Angular quadrupole due to two positive and two negative  $\pi$ -disclinations at the corners of a quadrilateral. (e) The director field corresponding to the texture in (d); the black and red lines are along the dark and bright bands of the pattern. (f) A network of quadrupoles as seen using crossed polarizers with a full-wave plate.

**Investigators: K. S. Krishnamurthy and Pramod Tadapatri**

### **6.30 COMPETING INSTABILITY MODES IN AN ELECTRICALLY DRIVEN BENT-CORE NEMATIC LIQUID CRYSTAL**

Bent-core nematic electroconvection is a relatively less explored area, particularly in the low frequency regime. We focus here mainly on the instabilities occurring below 100 Hz in an

initially planar monodomain of a bent-core nematic liquid crystal, which is negative in both conductivity and dielectric anisotropies. An unprecedented observation is the occurrence of three distinct bifurcation modes in a narrow region (10 Hz-17 Hz) that manifest, in the order of increasing threshold, as longitudinal, oblique and normal rolls. While the second of these is the flexoelectrically enabled Carr-Helfrich mode, the other two are nonstandard electroconvection modes. Significantly, the first two instabilities remain unquenched even after bifurcation into the normal roll state below their respective codimension-2 points. The hybrid roll states display complex flows and morphologies. The study includes measurement of relevant electrical parameters.



**Figure :** (Left) The critical voltage  $V_c$  for various patterned states as a function of frequency  $f$  at  $88^\circ\text{C}$  in a 11Cl sample of thickness  $5.5\ \mu\text{m}$ . Acronyms: ORs- Oblique Rolls, LRs- Longitudinal Rolls, INRs-Inplane Normal Rolls, TS-Time-dependent state, and PNDS- Propagating Normal Defect;  $f_{21}$  - frequency of transition between the INR2 and INR1 states.

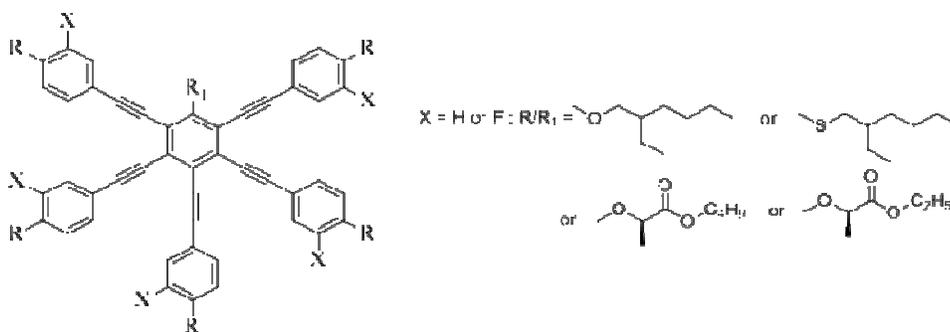
(Right) (a-c) Hybrid LR-INR2 texture at 80 Hz: (a) Birefringent 'beads' under partially crossed polarizers; 21 V; (b) Same as (a) but under a single polarizer, showing the beads as focal images. (c) Quasiturbulent hybrid state extending from right to left at 26 V; partially crossed polarizers. (d) The texture of INRs at 500 Hz under slightly uncrossed polarizers; 22 V.  $2\ \mu\text{m}$  scale division.

This work has been published: Pramod Tadapatri and K. S. Krishnamurthy, *J. Phys. Chem. B* **116**, 782-793 (2012).

**Investigators:** K. S. Krishnamurthy and Pramod Tadapatri

### 6.31 EFFECT OF BRANCHING, FUNCTIONAL GROUP AND MOLECULAR SYMMETRY ON MOLECULAR SELF-ORGANISATION

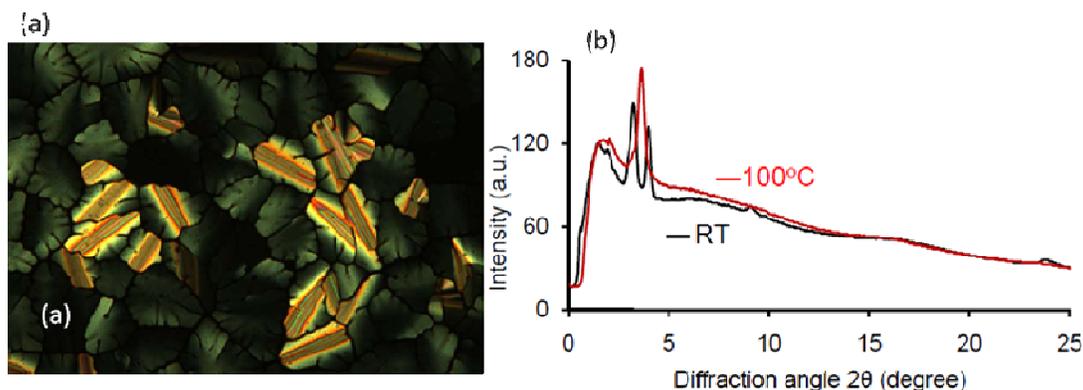
To study the key features like branching, functional group and molecular symmetry effects of polyalkynylbenzene (PAB) molecules which determine the mesophase formation and stability, a series of novel symmetrical and non-symmetrical polyalkynylbenzene-based chiral and achiral disc-shaped materials with respectively five and six 2-ethylhexyl peripheral aliphatic chains are synthesized. The symmetrical and non-symmetrical PAB were prepared by Sonogashira coupling of hexabromobenzene or monofunctionalized pentabromobenzene with phenylacetylenes substituted by 2-ethylhexyl peripheral chains (figure 1). The phenylacetylene bearing 2-ethylhexyl peripheral aliphatic chains via oxygen (OR) or sulphur (SR) or ester (CO<sub>2</sub>R, without branched chain) functions to balance steric and space-filling effects of the peripheral branched chains.



**Figure 1 :** Molecule and different substitutions used.

The symmetrical hexaalkynylbenzene with different functional group did not melt till 275 °C. To reduce the transition temperatures ‘molecular symmetry effect’ was applied successfully. As a result, most of the non-symmetrical compounds exhibit the Col<sub>n</sub> and/or Col<sub>r</sub>, which was confirmed by XRD study, and mesophases are stable at room temperature. In these cases, the

molecular self-assembly of columnar phases is unusual in that the transitions enthalpies especially clearing ( $Col_h$ -I) transition was not detected by DSC (figure 2). These effects must be considered to achieve the fine balance of properties of PAB molecules which lead to columnar mesophase formation. These are the first thermotropic discotic materials having the chiral/non-chiral carbon atoms substituted with the sulphur heteroatom that exhibit room-temperature columnar mesophases.



**Figure 2 :** (a) Texture of Col phases under POM at room temperature; (b) XRD pattern of  $Col_h$  and  $Col_r$  phase at room temperature (black) and 100°C (red).

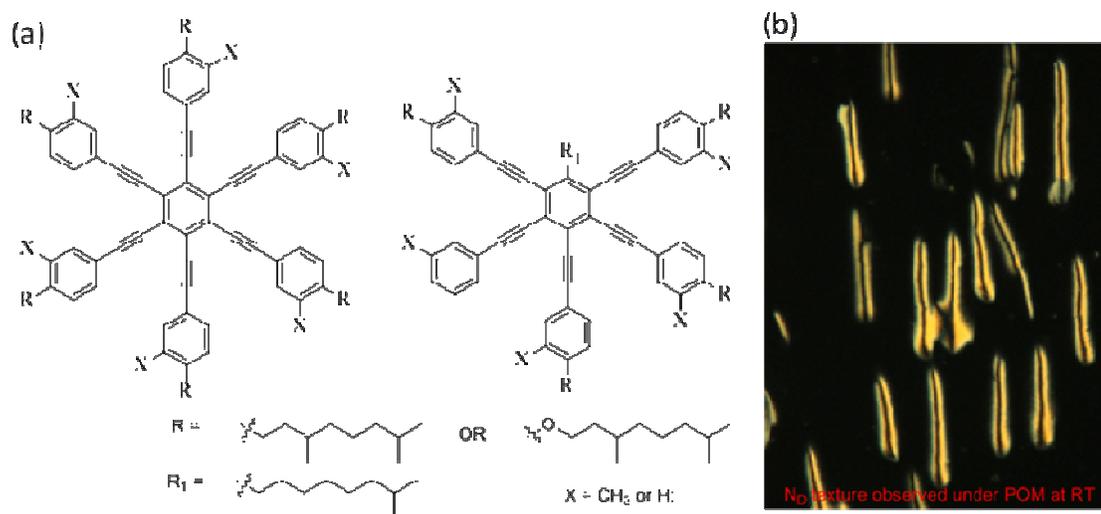
This work was carried out in collaboration with Prof. H. Takezoe, Tokyo Institute of Technology, Japan. This work has been published: S.K.Varshney, H. Nagayama, V. Prasad, H. Takezoe, *Liq. Cryst.*, **38**, 1321 (2011).

**Investigators:** S.K. Varshney and Veena Prasad

### **6.32 ROOM-TEMPERATURE DISCOTIC CHOLESTERIC AND NEMATIC PHASES WITHOUT THE STEREOHETEROGENEITY**

A series of new radial symmetrical and non-symmetrical polyalkynylbenzene-based chiral and achiral disc-shaped materials with respectively five and six 3,7-dimethyloctyl peripheral aliphatic chains is synthesized. The phenylacetylene bearing 3,7-dimethyloctyl peripheral

aliphatic chains via oxygen (OR) or directly to the phenyl ring (R) functions to balance steric and space-filling effects of the peripheral branched chains (figure 1(a)). These molecules exhibit the nematic or chiral nematic phase in wide temperature ranges. The alkynyl-substituted compounds (R) have the stereoheterogeneity problem that affects the transition temperatures. To overcome this problem, alkoxy-substituted compounds were prepared. These compounds are thermally stable. The effects of molecular symmetry and methyl substitution were examined. We found that most of symmetrical and non-symmetrical molecules exhibit the  $N_D$  mesophase with a wide thermal range. Particularly the non-symmetrical ones exhibit the nematic or cholesteric mesophases well below and above the ambient temperature. The introduction of a methyl substituent increases the isotropization temperature in both symmetrical and non-symmetrical compounds. As a result in non-centrosymmetric compounds, viscous liquid at room temperature changes to  $N_D$  or  $N_D^*$  phase at RT in methyl substituted compounds (figure 1(b)). This fact in turn suggests, there exists  $N_D$  or  $N_D^*$  phase below viscous liquid even in compounds without a methyl substitution.



**Figure 1 :** (a) molecule and substitutions used; (b) texture of  $N_D$  phase at RT.

These molecular tailoring significantly affects the intermolecular attractive forces and as a result self-assembled molecules affect the melting, clearing temperatures and the molecular packing.

This work was carried out in collaboration with Prof. H. Takezoe, Tokyo Institute of Technology, Japan.

**Investigator: S.K. Varshney**

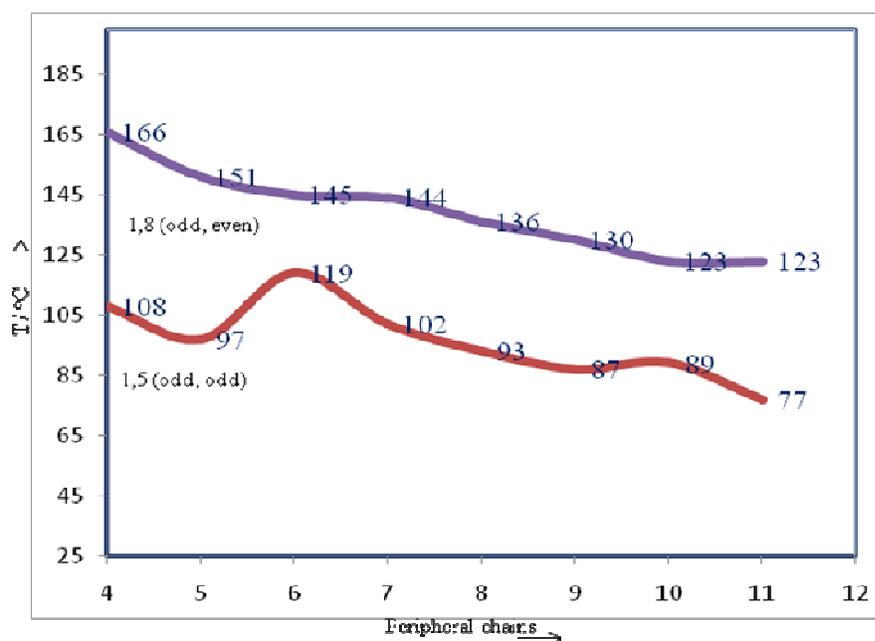
### **6.33 STRUCTURAL ISOMERISM OF FUNCTIONALIZED TRIPHENYLENE DISCOTIC LIQUID CRYSTALS**

Molecular functionalisation is an important aspect in the molecular engineering of triphenylene (TP) central core. Regioselective electrophilic aromatic substitution reaction of hexaalkoxytriphenylene [TP(OR)<sub>6</sub>] or monochlorohexaalkoxytriphenylene [TP(OR)<sub>6</sub>Cl] gives the two positional isomers 1,8 (odd, even) and 1,5 (odd,odd)-dinitrohexaalkoxytriphenylene or 5,12 (odd, even) and 5,9 (odd, odd)-dinitromonochlorohexaalkoxytriphenylene. Their mesomorphism was investigated by POM and DSC analysis. Interestingly, *odd-odd*-dinitrohexabutyloxytriphenylene [TP(OC<sub>4</sub>H<sub>9</sub>)<sub>6</sub>(NO<sub>2</sub>)<sub>2</sub>] is a crystalline solid where as *even-odd*-dinitrohexabutyloxytriphenylene [TP(OC<sub>4</sub>H<sub>9</sub>)<sub>6</sub>(NO<sub>2</sub>)<sub>2</sub>] exhibits the columnar mesophases and higher homologous of both the isomers exhibit the columnar mesophase with wide thermal range. An *even-odd*-TP(OR)<sub>6</sub>(NO<sub>2</sub>)<sub>2</sub> compound exhibit the higher clearing temperature compared to *odd-odd*-TP(OR)<sub>6</sub>(NO<sub>2</sub>)<sub>2</sub> compound. Similarly, *odd-odd-odd*-TP(OR)<sub>6</sub>Cl(NO<sub>2</sub>)<sub>2</sub> are liquid at RT and *even-odd-odd*-TP(OR)<sub>6</sub>Cl(NO<sub>2</sub>)<sub>2</sub> exhibit the columnar mesophase.

Further, single crystal structure of *odd-odd* isomer was studied to establish the positions of the nitro functional group. The structure of compound *odd-odd*-TP(OC<sub>4</sub>H<sub>9</sub>)<sub>6</sub>(NO<sub>2</sub>)<sub>2</sub> is elucidated by single crystal data that shows that the molecule is planar and it crystallizes into

triclinic space group P-1. There are three crystallographically independent molecules in the asymmetric unit. The C-H...O, C-H...N type of intermolecular hydrogen bonds and C-H... $\pi$  weak interactions stabilize the molecules in the unit cell in addition to the  $\pi$ - $\pi$  interactions.

Interestingly, odd-odd isomer exhibits the lower clearing temperatures compared to even-odd isomer (figure), thus it can be proposed that the even-odd isomer is symmetrical and odd-odd is unsymmetrical but based on the chemical structure it is reversed. The introduction of such substituent boosts the mesomorphism. The chemical versatility of aryl nitro group suggests that it provides a key for the introduction of other functionalities for a variety of substituents in rigid discotic cores.



**Figure :** Isotropic temperatures of odd, odd and odd, even isomers with respect to aliphatic chains.

This work was carried out in collaboration with Vivek Gupta, Jammu University, Jammu.

**Investigator:** S.K. Varshney

## 7. SPONSORED PROJECTS

- An Indo-Bulgarian research project proposal entitled “Investigations on flexoelectric properties of liquid crystals” was sanctioned by DST in February 2008. Under this project, Dr.C.V.Yelamaggad, of this Centre visited Institute of Solid State Physics, Bulgarian Academy of Sciences, Sofia, Bulgaria during 20 June to 4 July 2011. The project came to an end during the year. [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]
- Under the ongoing INSA-Hungarian Exchange Programme, Mr. Peter Salamon, Hungarian Scientist, Research Institute for Solid State Physics and Optics, Hungarian Academy of Sciences, Budapest, Hungary visited the Centre during 31 October to 11 November 2011 and gave a seminar entitled “Novel experimental investigations of flexodomains”.
- A project proposal “Charge transport and calorimetric studies on liquid crystals and plastic crystals doped with metal nanoparticles” in collaboration with Dr. B.L.V. Prasad, NCL, Pune, was submitted to DST. This project proposal has been sanctioned. [Investigator: S.Krishna Prasad]
- 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. [Investigator: Uma S. Hiremath and Project Mentor: Geetha G. Nair].
- A fast-track project proposal titled “Magnetic studies on magnetic ion doped ZnO thin films and resistive switching applications” was submitted under the Scheme for Young

Scientists to Department of Science and Technology (DST). This project proposal has been sanctioned for funding by DST. [Investigator: S.Angappane].

- A fast-track project proposal entitled “Local conductance, gas sensing and molecular magnetism studies of electroactive systems based on Metal –Phthalocyanines” was submitted under the Scheme for Young Scientists to DST. The project proposal has been sanctioned for funding by DST. [Investigator: Neena Susan John].

## **8. WOMEN’S DAY**

The International Women’s Day was celebrated on 8 March 2012. On this occasion,



*Dr. R.Pratibha delivering a talk on “Women Scientists – Struggles and Achievements” on the occasion of the International Women’s Day.*

Dr.R.Pratibha, Associate Professor, Raman Research Institute, Bangalore gave a talk titled "Women Scientists – Struggles and Achievements". The lecture was followed by a lively discussion with the faculty and students. The women staff members of the Centre participated in the meeting.



*Women members of CSMR at a meeting on the occasion of International Women's Day.*

## **9. NATIONAL SCIENCE DAY**

The Centre celebrated the National Science Day on 28 February 2012, declaring it the Open Day for the public. The occasion was celebrated by organizing a series of lectures by the CSMR scientists for an invited audience consisting of about 45 students and a few teachers of ZOY School, Vidyaranyapura, Bangalore. The talks were on :

<b>Title</b>	<b>Speaker</b>
Crystals: The nature's wonders!!	Prof. H. L. Bhat
Geometry in nature	Prof. K. S. Krishnamurthy
Scientific discoveries by school students	Prof. G.S.Ranganath
Nature, Science, Nobel prize and 300 million dollars	Prof. K.A.Suresh

The school students visited the laboratories and interacted with the researchers. Some special demonstrations were conducted to explain the research activities.



*Ms. T. Shilpa Harish describing shear deformation studies on soft matter employing a Rheometer.*



*Mr. Pramod Tadapatri demonstrating the surface topology measurements with a confocal microscope.*



*Ms. R. Rajalakshmi describing the measurements of some magnetic parameters using a squid magnetometer.*



*Dr. Sanjay K. Varshney explaining some chemical reactions in the synthesis of discotic liquid crystals.*



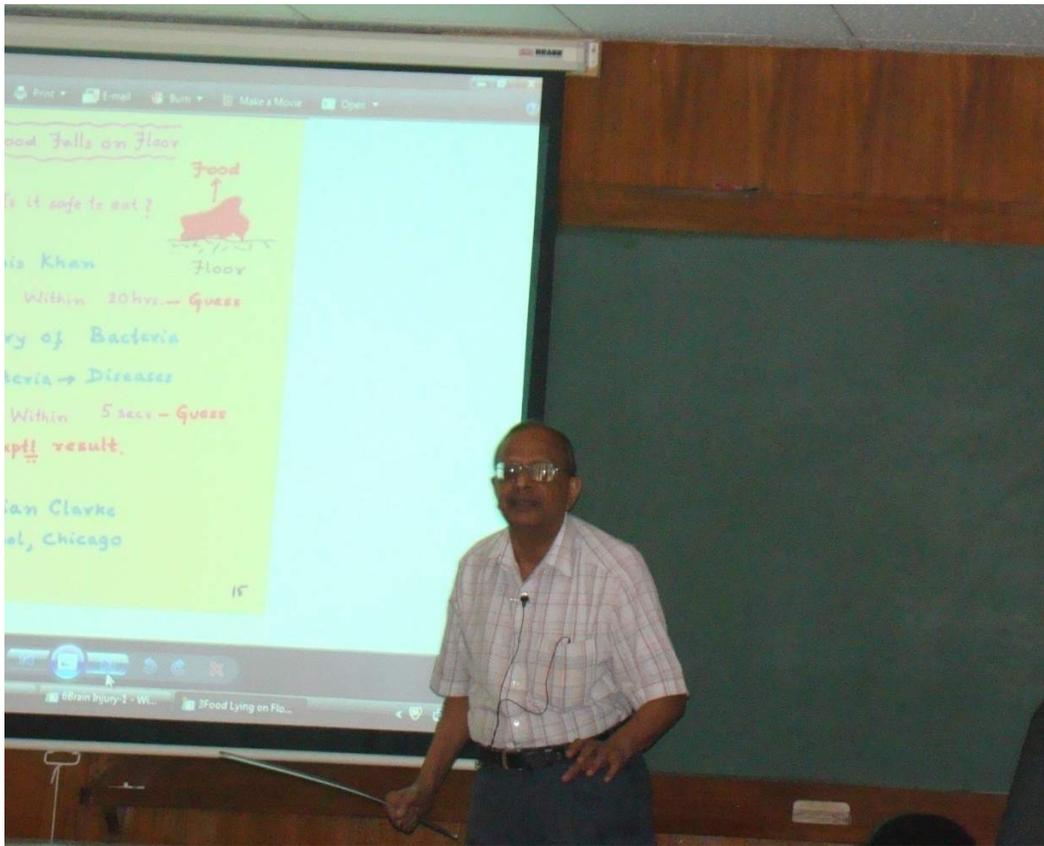
*Mr. M. Vijaykumar and Ms. P. Lakshmi Madhuri explaining the studies on confined ferroelectric liquid crystals using 1 D X-ray diffractometer.*



*Mr. K. R. Vinaya Kumar explaining some optical measurements on thin films using an imaging ellipsometer.*



*Ms. R. Bhargavi giving a demonstration of shear thinning properties of some liquid crystalline gels.*



*Prof. G. S. Ranganath delivering a talk on “Scientific discoveries by school students” on the occasion of the National Science Day.*



*Prof. K. A. Suresh delivering a talk on “Nature, Science, Nobel prize and 300 million dollars” on the occasion of the National Science Day.*

## 10. PROF. S. CHANDRASEKHAR MEMORIAL LECTURE

The 8<sup>th</sup> Prof. S. Chandrasekhar Memorial Lecture was delivered by Prof. G. Padmanaban, NASI-Platinum Jubilee Chair & Honorary Professor, Department of Biochemistry, Indian Institute of Science, Bangalore on 5 August 2011. The lecture was on “Growth of Biotechnology in India”. Prof. R. Narasimha, Chairman, Governing Council presided over the function.



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



*Prof. K. A.Suresh introducing the speaker, Prof. G. Padmanabhan.*



*Prof. G. Padmanabhan delivering the Prof. S. Chandrasekhar Memorial talk on “Growth of Biotechnology in India”.*



*A section of the audience engrossed in the lecture.*



*Conveying a 'point to note' on growth of Biotechnology.*

## 11. INTERNATIONAL YEAR OF CHEMISTRY 2011

The Centre celebrated the International Year of Chemistry 2011 on 27 December 2011. The following lectures were given :

<b>Title</b>	<b>Speaker</b>
Evolution of dendritic macromolecules in the garb of modern polymer structures and architectures	Keynote address by Prof. N. Jayaraman Indian Institute of Science Bangalore
Nanoscale aspects of crystal growth	Dr. Neena Susan John
Supramolecular functional liquid crystals: Novel self-complementing mesogens derived from amino acids	Dr. C. V. Yelamaggad
Chemistry of functionalized triphenylene	Dr. Sanjay Kumar Varshney
Photochromic plasmid-like liquid crystalline materials	Ms. N. G. Nagaveni
A new class of low molar mass non-symmetrical achiral dimer-like liquid crystals	Ms. Rashmi Prabhu
Multiferroics: Different ways to combine magnetism and ferroelectricity	Dr. S. Angappane
Physics and chemistry of crystal growth	Prof. H. L. Bhat
Recent trends in chemistry – Nobel Prizes	Prof. K. A. Suresh

## 12. STUDENTS' PROGRAMME

- Mr. G. Shanker was awarded the Ph.D. degree of the University of Mangalore, Mangalore for his thesis entitled "Studies of liquid crystals with novel molecular architecture: design, synthesis and characterization".
- Mr. Pramoda Kumar was awarded the Ph.D. degree of the University of Mangalore, Mangalore for his thesis entitled "Field driven reorientational and convective instabilities in nematic liquid crystals".

- Ms. S. Sridevi, SRF submitted her Ph.D. thesis entitled “Experimental investigations on polar liquid crystals” to Mangalore University during the year.
- Mr. M. Vijay Kumar, Ms. N. G. Nagaveni, Ms. T. Shilpa Harish, Ms. H. N. Gayathri, Ms. Hashambi K. Dambal, Mr. K. R. Vinaya Kumar, Ms. R. Bhargavi and Ms. Rashmi Prabhu attended and made poster presentations at the 18<sup>th</sup> National Conference on Liquid Crystals during November 15-17, 2011, Organized by Department of Physics, NERIST, Nirjuli (Itanagar), Arunachal Pradesh.
- During the year, three new students joined CSMR for the Ph.D. Programme.



*Prof. N. Jayaraman delivering the keynote address on “Evolution of dendritic macromolecules in the garb of modern polymer structures and architectures” on the occasion of the International Year of Chemistry 2011.*

### **13. AWARDS / HONORS**

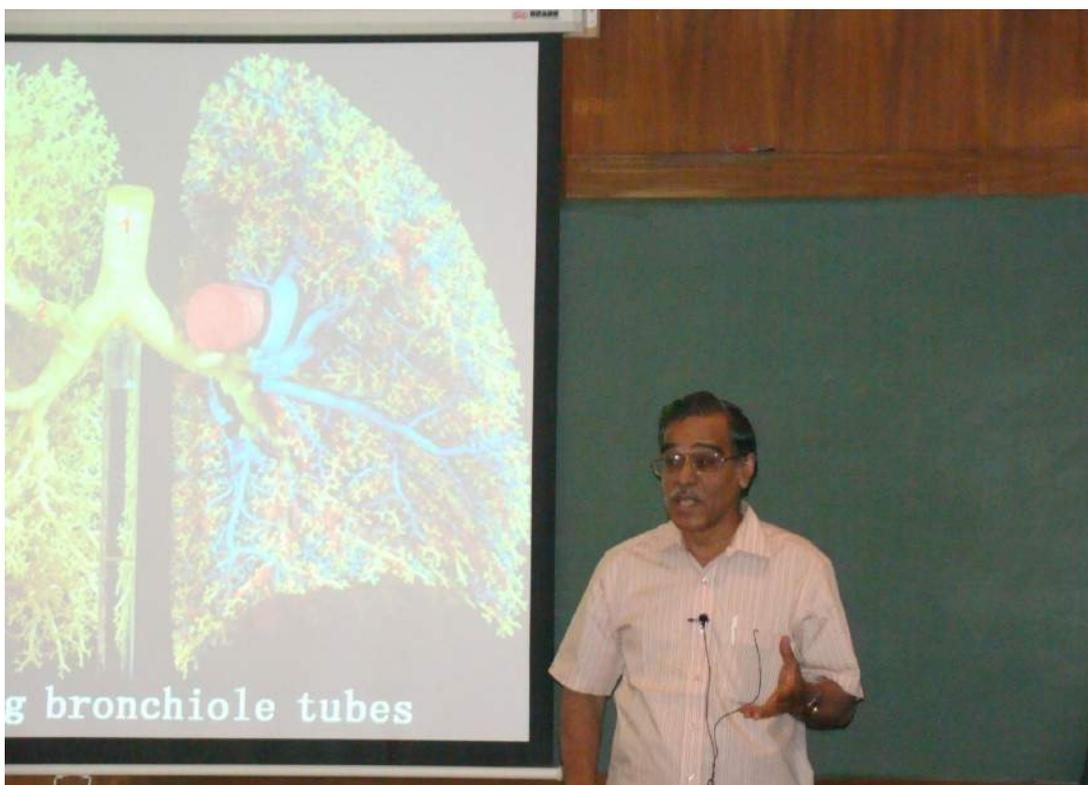
- Dr. S. Krishna Prasad was invited to be a member of the International Advisory Committee for the 2nd International Symposium on Liquid Crystals: Science and Technology held during 17-19 July 2011, Changzhou, China.

- Dr. Geetha G. Nair was invited to be a member of the International Advisory Committee for the 2nd International Symposium on Liquid Crystals: Science and Technology held during 17-19 July 2011, Changzhou, China.
- Dr. D. S. Shankar Rao received the Sir C. V. Raman Young Scientist Award in the field of Physics for the year 2010, instituted by the Karnataka State Council for Science & Technology. The award function was held on January 31, 2012 at J. N. Tata Auditorium, Indian Institute of Science, Bangalore-560 012.
- Ms. Rashmi Prabhu won the Dewan Jawahar Lal Nayar Memorial Prize for Best Poster presentation in Chemistry at the 18<sup>th</sup> National Conference on Liquid Crystals held at NERIST, Nirjuli (Itanagar), Arunachal Pradesh during November 15-17, 2011.
- Ms. R. Bhargavi won the Dewan Jawahar Lal Nayar Memorial Prize for Best Poster presentation in Physics at the 18<sup>th</sup> National Conference on Liquid Crystals held at NERIST, Nirjuli (Itanagar), Arunachal Pradesh during November 15-17, 2011.

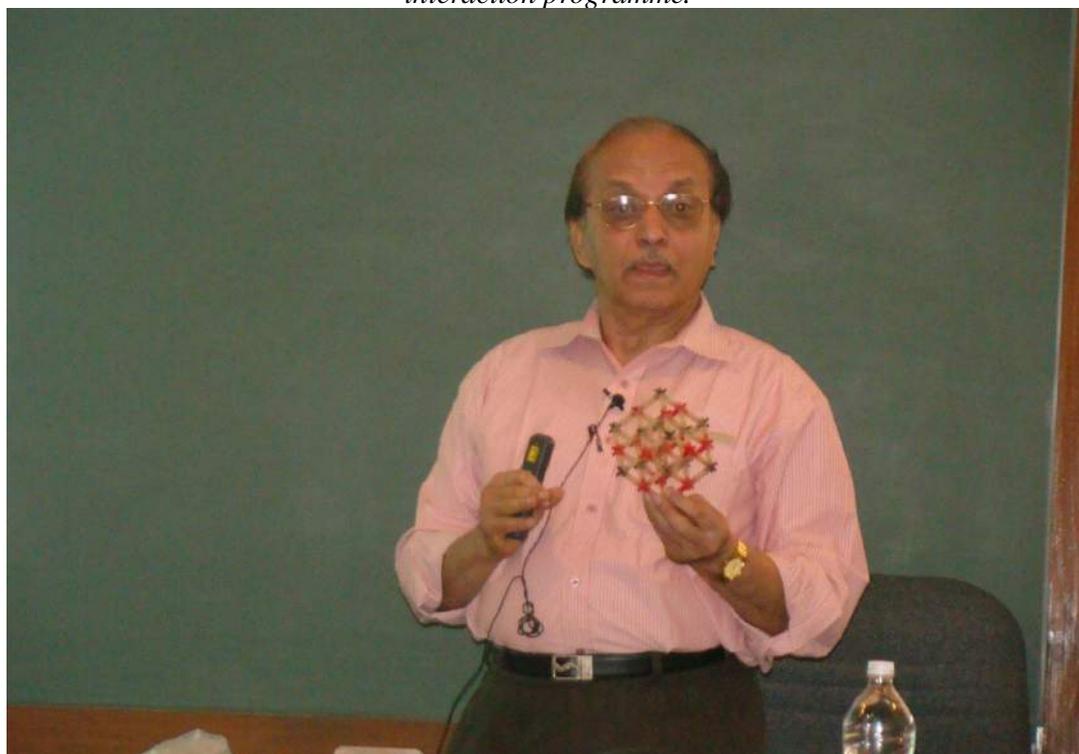
#### 14. POPULARIZATION OF SCIENCE :

##### DR. S. KRISHNA PRASAD

	Name of the Institute	Date	Title of talk
1.	Karnataka Rajya Vijnana Parishat, Shravanabelagola	19-12-2011	Various aspects of Liquid Crystals and Nanotechnology
2.	Karnataka Rajya Vijnana Parishat, Gangavati	26-12-2011	
3.	Karnataka Rajya Vijnana Parishat, Kampli	26-12-2011	
4.	Karnataka Rajya Vijnana Parishat, Bangalore	06.03.2012	



*Prof. K. S. Krishnamurthy delivered many lectures organized by the Karnataka Rajya Vijnana Parishat in various zones under Karnataka Vijnana Vidya Jagruthi: Student-Scientist interaction programme.*



*Prof. H. L. Bhat delivered many lectures under the INSPIRE programme of DST at various centres and also gave talks under the Karnataka Rajya Vijnana Parishat.*

**DR. C.V.YELAMAGGAD**

	<b>Name of the Institute</b>	<b>Date</b>	<b>Title of talk</b>
1.	Sir. C. V. Raman Hall, Central College, Bangalore University, Bangalore  Served as a resource person for UGC sponsored refresher course program for college lecturers.	15-03-2012	Chemistry Aspects of Liquid Crystals
2.	J.M.J. College for Women, Tenali. Andhra Pradesh.  Served as a resource person for UGC sponsored two days (24 -25 Jan 2012) work shop on "Soft Materials"	25-01-2012	Supramolecular Liquid Crystals: Dipeptides
3.	Anjuman Arts, Commerce and Science College, Bijapur.  Served as a resource person for the Scientists-Students Interactive Program Organized by KRVP (Karnataka Rajya Vijnana Parishat), through Govt. of Karnataka, to popularize Science among high School and College Students.	20-01-2012	Liquid crystals: An Unique State of Matter
4.	Millennium Public School, Bidar.  Served as a resource person for the Scientists-Students Interactive Program Organized by KRVP through Govt. of Karnataka, to popularize Science among high School and College Students.	08-01-2012	Liquid crystals: An Unique State of Matter
5.	Naland PU College, Gulbarga.  Served as a resource person for the Scientists-Students Interactive Program Organized by KRVP through Govt. of Karnataka, to popularize Science among high School and College Students.	07-01-2012	Liquid crystals: An Unique State of Matter
6.	V. V. S. First Grade College for Woman, Basaveshwar Nagar, Bangalore.	03-01-2012	Liquid Crystals: An unique state of Matter.

Served as Resource Person for INSPIRE-2012, organized by Science Nurture Camp, DST Govt. of India.

- |    |  |            |  |
|----|--|------------|--|
| 7. | Shri Prabhu Arts and J. N. B Degree College, Surpur. | 29-12-2011 | Liquid crystals: An Unique State of Matter |
|----|--|------------|--|

Served as a resource person for the Scientists-Students Interactive Program Organized by KRVP through Govt. of Karnataka, to popularize Science among high School and College Students.

- |    |  |            |  |
|----|--|------------|--|
| 8. | Adichunchangiri Institute of Technology, Chikmagalur | 08-12-2011 | Liquid crystals: An Unique State of Matter |
|----|--|------------|--|

Served as a resource person for the Scientists-Students Interactive Program Organized by KRVP through Govt. of Karnataka, to popularize Science among high School and College Students.

**DR. S. ANGAPPANE**

	<b>Name of the Institute</b>	<b>Date</b>	<b>Title of talk</b>
1.	BrainSTARS, Bangalore	17-03-2012	Multiferroics

**PROF. K. S. KRISHNAMURTHY**

	<b>Name of the Institute</b>	<b>Date</b>	<b>Title of talk</b>
1.	Karnataka Rajya Vijnana Parishat Madhugiri Zone	04-12-2011	
2.	Karnataka Rajya Vijnana Parishat Gadag Zone	11-01-2012	
3.	Karnataka Rajya Vijnana Parishat Hubli Zone	12-01-2012	Liquid crystals and modulation of light
4.	Karnataka Rajya Vijnana Parishat Davanagere Zone	21-01-2012	

**PROF. G. S. RANGANATH**

	<b>Name of the Institute</b>	<b>Date</b>	<b>Title of talk</b>
1.	Jawaharlal Nehru Planetarium, Bangalore	29.04.2011 and 30.04.2011	Image formation : Camera eyes in animals- Two lectures
2.	Jawaharlal Nehru Planetarium, Bangalore	09.07.2011, 16.07.2011, 23.07.2011, 30.07.2011	Course on thermal physics- Four Lectures
3.	DST INSPIRE Programme, Bangalore University	21.01.2012	Interesting problems in Physics
4.	Jawaharlal Nehru Planetarium, Bangalore	10.02.2012	Simple and elegant experiments
5.	Physics Workshop for College Lecturers- Bangalore University	21.03.2012	Thought provoking ideas and experiments in physics-Two lectures

**PROF. H. L. BHAT**

	<b>Name of the Institute</b>	<b>Date</b>	<b>Title of talk</b>
1.	Regional Institute of Education, Mysore	04.04.2011	1. Lasers: Principles 2. Lasers: Applications
2.	Bangalore Science Forum, Basavangudi, Bangalore	12.05.2011	Laser as a teaching Aid (Valedictory address)
3.	Kendriya Vidyalaya, CV Raman Nagar, Bangalore	14.05.2011	Electromagnetic waves and photo electric effect
4.	Alva's Pre –University College, Moodbidri	20.09.2011	Laser world
5.	Vivekananda Degree College, Puttur	08.03.2012	Laser: Light of the 20 <sup>th</sup> century
6.	Vivekananda college of Engineering and Technology, Puttur	08.03.2012	Laser: Light of the 20 <sup>th</sup> century
7.	Maharani's Arts and Science College Bangalore	29.03.2012	Lasers : Past, present and future.

8.	Central College, Bangalore (Refresher course for college teachers)	31.03.2012	1.Laser: Light of the 20 <sup>th</sup> century 2. Laser as a teaching aid
9.	Karnataka Rajya Vijnana Parishat programme at A.I.T. College, Chikkamagaluru	08.12.2011	Photons to laser: Sixty years of scientific endeavour
10.	Karnataka Rajya Vijnana Parishat programme at Siddaganga College of Pharmacy, Tumkur	09.12.2011	Lasers and their applications
11.	Karnataka Rajya Vijnana Parishat Programme at District Science Center, Karwar	15.12.2011	Electromagnetic radiation and laser
12.	Karnataka Rajya Vijnana Parishat programme at Shraavanabalagola, Hasan Dist.	20.12.2011	Photons to Laser: Sixty years of scientific endeavour
13.	Karnataka Rajya Vijnana Parishat Programme at Ambedkar Bhavan, Shimoga	26.12.2011	Photons to Laser: Sixty years of scientific endeavour
14.	Karnataka Rajya Vijnana Parishat programme at Kollegal	07.01.2012	Laser: Light of the 20 <sup>th</sup> century
15.	Karnataka Rajya Vijnana Parishat programme at Mysore	07.01.2011	Einstien to Theodre Maiman: The laser connection
16.	INSPIRE Programme at I Square IT, PUNE	26.06.2011	Nuclear energy and crystals
17.	INSPIRE Programme at Siddaganga College of Arts, Science and Commerce for Women, Tumkur	12.12.2011	Laser: Light of the 20 <sup>th</sup> century
18.	INSPIRE Programme at NIT, Calicut	21.12.2011 22.12.2011	Science and technology of lasers (2 lectures)
19.	INSPIRE Programme at VVS First Grade College for Women, Bangalore	30.12.2011	Laser: Light of the 20 <sup>th</sup> century

## 15. VISITS ABROAD

- Dr. S. Krishna Prasad attended the 2nd International Symposium on Liquid Crystals: Science and Technology held at Changzhou, China during 17-19th July 2011 and gave an invited talk entitled “Diminution of the ordering in plastic and liquid crystalline phases by confinement”, and also Chaired a Session during the conference.
- Dr. Geetha G. Nair attended the 2nd International Symposium on Liquid Crystals: Science and Technology held at Changzhou, China during 17-19th July 2011 and gave an invited talk entitled “Anomalously large bend elastic constant and faster electro-optic response in soft glassy gels formed by a dipeptide gelator”.
- Dr. C. V. Yelamaggad visited the Institute of Solid State Physics, Bulgarian Academy of Sciences, Sofia, during 20 June to 4 July 2011 as a part of the ongoing Indo-Bulgarian collaboration. He gave a lecture, titled “Supramolecular liquid crystals: facile synthesis and characterization of novel self-complementing systems derived from amino acids”. He also gave another lecture titled “Supramolecular liquid crystals: facile synthesis and characterization of novel self-complementing systems derived from amino acids”, at the Institute of Organic Chemistry with Centre of Phytochemistry, on June 27, 2011.
- Dr. S. Angappane attended the 15<sup>th</sup> International Conference on Thin Films (ICTF-15) held at Kyoto, Japan during 8-11 Nov 2011 and made an oral presentation entitled “Enhanced magnetic properties of BiFeO<sub>3</sub> using ZnO buffer layer”.

## 16. SEMINARS / TALKS GIVEN AT OTHER INSTITUTES

- Prof. K. A. Suresh attended the International Conference on Synthetic & Structural Chemistry – ICSSC-2011 during December 8-10, 2011 held at Mangalore University,

Mangalore as a Chief Guest and gave the Inaugural Address entitled “Recent trends in structural chemistry”.

- Prof. K. A. Suresh attended the 18<sup>th</sup> National Conference on Liquid Crystals held at Itanagar, Arunachal Pradesh, during November 15–17, 2011 and gave an invited talk on "Spatiotemporal patterns in a monolayer at air-water interface".
- Dr. S. Krishna Prasad attended the 18<sup>th</sup> National Conference on Liquid Crystals held at Itanagar, Arunachal Pradesh, during November 15–17, 2011 and gave an invited talk on "The de Vries smectic A phase and the antiferroelectric structure", and also chaired a session.
- Dr. S. Krishna Prasad attended the workshop “Materials for advanced technology” held at Jain University, Bangalore during May 14-15, 2011 and gave an invited talk entitled “Liquid crystals: exemplary soft materials for bio/engineering applications”.
- Dr. K. S. Krishnamurthy attended the 18<sup>th</sup> National Conference on Liquid Crystals held at Itanagar, Arunachal Pradesh, during November 15–17, 2011 and gave an invited talk on "Generation and Stability of Half-strength Twist Disclination Loops in Nematic Liquid Crystals".
- Prof. H. L. Bhat attended the State Level Seminar on Laser Technology: Frontiers and Applications held at SDM College, Ujire, Karnataka during 25-26 August 2011 and gave keynote address entitled “Lasers: Past, Present and Future”.
- Prof. H. L. Bhat visited School of Physics, Madurai Kamaraj University, Madurai on 8 September 2011 and gave a talk on “Instrumentation in Crystal Growth” (Indian Academy of Sciences Endowment Lecture).

- Dr. Geetha G. Nair attended the 18<sup>th</sup> National Conference on Liquid Crystals held at Itanagar, Arunachal Pradesh, during November 15–17, 2011 and gave a talk on " Liquid Crystal Gels: Electrical, Rheological and Structural Properties".
- Dr. C. V. Yelamaggad attended the 18<sup>th</sup> National Conference on Liquid Crystals held at Itanagar, Arunachal Pradesh, during November 15–17, 2011 and gave a talk on "Synthesis and phase transitional behavior of dimer-like optically active liquid crystals".
- Dr. D. S. Shankar Rao attended the 18<sup>th</sup> National Conference on Liquid Crystals held at Itanagar, Arunachal Pradesh, during November 15–17, 2011 and gave a talk on "High pressure investigations of a ferroelectric liquid crystal exhibiting a trend reversal in the thermal variation of polarization".
- Dr. P. Viswanath attended the 18<sup>th</sup> National Conference on Liquid Crystals held at Itanagar, Arunachal Pradesh, during November 15–17, 2011 and gave a talk on "Non-linear spectroscopic studies of anions at the air-electrolyte interface".
- Dr. Sanjay K. Varshney attended the 18<sup>th</sup> National Conference on Liquid Crystals held at Itanagar, Arunachal Pradesh, during November 15–17, 2011 and gave an talk on "Probing the influence of peripheral aliphatic chains and molecular symmetry: Control the molecular self-organising process and stability at room temperature ".
- Dr. C. V. Yelamaggad visited the Siddheshwar High School, Shiroor during 28 November 2011 and gave a talk entitled "Chemistry of Liquid Crystals" on the occasion of celebrating International Year of Chemistry 2011.
- Dr. C. V. Yelamaggad visited the Department of Chemistry, Central College, Central College Campus, Bangalore during 10 December 2011 and gave an invited talk entitled "Chemistry

of Liquid Crystals” on the occasion of celebrating International Year of Chemistry 2011, organized by Department of Chemistry in association with UGC.

- Dr. C. V. Yelamaggad visited the S.D.M. College, Ujire during 13 December 2011 and gave an invited talk entitled “Chemistry of Liquid Crystals”. This program was organized, in association with UGC, to celebrate International Year of Chemistry 2011 (ICY-2011).
- Prof. H. L. Bhat visited the Crystal Growth Centre, Anna University, Chennai on 8 January 2012 and gave a talk on “Crystals for Nonlinear Optical Applications: Growth and Characterization”.
- Dr. S. Krishna Prasad attended the National Workshop on Soft Materials held at Tenali, Andhra Pradesh during January 24-25, 2012, and gave an invited Lecture entitled “Many facets of soft matter”.
- Dr. P. Viswanath attended the workshop on “Micro and Nano fabrication” at IIT Kanpur during February 27 to March 2, 2012.
- Prof. H. L. Bhat attended the International Workshop in Photonics and Optical Materials held at SSN College of Engineering, Chennai during 6-8 February 2012 and gave a talk entitled “Growth and properties of technologically important NLO Crystals”.
- Prof. H. L. Bhat attended the International Conference on Recent trends in Advanced Materials (ICRAM 2012) held at VIT, Vellore during 20-22 February 2012 and gave an invited talk entitled “Growth and Properties of Cesium Lithium Borate single crystals”.
- Dr. C. V. Yelamaggad visited Department of Chemistry and Chemical Technology, Vidyasagar University, Midnapore, West Bengal, during 27 to 29 February 2012 and delivered 20 chemistry course lectures entitled “Liquid Crystals : Fundamentals, chemical

aspects and applications” to M.Sc. and Ph.D. students of organic chemistry as a visiting Professor [07 lectures on 27-Feb-2012; 08 lectures on 28-Feb-2012; 08 lectures on 29-Feb-2012].

## 17. LECTURES BY VISITORS

- Prof. K. Ohta, Shinshu University, Japan visited the Centre and gave a colloquium titled “Development of liquid crystalline phthalocyanine-fullerene dyads” on 8 November 2011.
- Prof. Satyendra Kumar, Kent State University, Kent, USA visited the Centre and gave a colloquium titled “Organization of hydrocarbon and siloxane molecular segments in de Vries smectic-A and C phases” on 8 November 2011.
- Dr. S. Anantha Ramakrishna, Indian Institute of Technology, Kanpur visited the Centre and gave a seminar titled “Plasmonic nanostructured materials for enhanced optical properties” on 22 December 2011.
- Under the ongoing INSA-Hungarian Exchange Programme, Dr. Tamas Borzsonyi, Research Institute for Solid State Physics and Optics, Hungarian Academy of Sciences, Budapest, Hungary visited the Centre on 19 January 2012 and gave a colloquium entitled “Orientational order and alignment of elongated particles induced by shear flow”.
- Mr. Peter Salamon, Research Institute for Solid State Physics and Optics, Budapest, Hungary visited the Centre under the ongoing INSA-Hungarian Exchange Programme Centre during 31 October to 11 November 2011 and gave a seminar entitled “Novel experimental investigations of flexodomains” on 4 November 2011.

- Dr. Sanat Karmakar, Jadavpur University, Kolkata visited the Centre and gave a seminar titled “Interaction of an antimicrobial peptide with phospholipid membranes: An antimicrobial activity” on 18 October 2011.
- Mr. Anujit Saha, Thomson Reuters, India visited the Centre and gave a seminar titled “New features and functionality in Web of Science Version 5.3” on 29 September 2011.

## 18. LIST OF SCIENTISTS AND RESEARCHERS

	<b>Name</b>	<b>Designation</b>
1.	Prof. K. A. Suresh	Scientist of Eminence
2.	Dr. S. Krishna Prasad	Scientist F
3.	Dr. Geetha G. Nair	Scientist D
4.	Dr. D. S. Shankar Rao	Scientist D
5.	Dr. Veena Prasad	Scientist D
6.	Dr. C. V. Yelamaggad	Scientist D
7.	Dr. P. Viswanath	Scientist C
8.	Dr. S. Angappane	Scientist C
9.	Dr. Neena Susan John	Scientist C
10.	Prof. K. S. Krishnamurthy	Emeritus Scientist
11.	Prof. H. L. Bhat	Visiting Professor
12.	Prof. G. S. Ranganath	Visiting Professor
13.	Dr. Uma S. Hiremath	Research Associate
14.	Ms. S. Sridevi	Senior Research Fellow*
15.	Mr. Pramod Tadapatri	Senior Research Fellow
16.	Mr. Prasad N. Bapat	Senior Research Fellow
17.	Ms. Rashmi Prabhu	Junior Research Fellow

18.	Ms. N. G. Nagaveni	Junior Research Fellow
19.	Ms. R. Bhargavi	Junior Research Fellow
20.	Mr. K. R. Vinaya Kumar	Junior Research Fellow
21.	Ms. T. Shilpa Harish	Junior Research Fellow
22.	Mr. M. Vijaykumar	Junior Research Fellow
23.	Ms. R. Rajalakshmi	Junior Research Fellow
24.	Ms. Hashambi K.Dambal	Junior Research Fellow
25.	Mr. Nagaiah Kambhala	Junior Research Fellow
26.	Ms. H. N. Gayathri	Junior Research Fellow
27.	Ms. Pappu Lakshmi Madhuri	Junior Research Fellow
28.	Ms. S. Vimala	Junior Research Fellow
29.	Mr. K. Bramhaiah	Junior Research Fellow

*\* Since submitted the thesis and left.*

## **19. ADMINISTRATIVE STAFF**

<b>Name</b>	<b>Designation</b>
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 Pradeep V. Hegde	Library Assistant
Shri Govindappa	Consultant in Administration

## 20. PUBLICATIONS DURING 2011-2012

### Technical Reports / Monographs

1. Book Chapter : Photo-stimulated phase transformations in liquid crystals and their non-display applications, C.V. Yelamaggad, S. Krishna Prasad and Q. Li, in *Liquid Crystals Beyond Displays: Chemistry, Physics and Applications*, Ed. Q. Li, John Wiley & Sons (in Press)

### Publications in Refereed Journals

1. Competing instability modes in an electrically driven bent-core nematic liquid crystal, Pramod Tadapatri and K. S. Krishnamurthy, *J. Phys. Chem. B*, **116**, 782 (2012).
2. Exchange bias behavior of monodisperse Fe<sub>3</sub>O<sub>4</sub>/γ-Fe<sub>2</sub>O<sub>3</sub> core/shell nanoparticles, Yosun Hwang, S. Angappane, Jongnam Park, Kwangjin An, T. Hyeon, Je-Geun Park, *Current Applied Physics*, **12**, 808 (2012).
3. Technologically promising, room temperature luminescent columnar liquid crystals derived from s-triazine core: molecular design, synthesis and characterization, Hashambi K. Dambal and C. V. Yelamaggad, *Tetrahedron Lett.*, **53**, 186(2012).
4. Studies on Langmuir monolayer of tricycloquinazoline based disk-shaped liquid crystal molecules, Raj Kumar Gupta, V. Manjuladevi, C. Karthik, Sandeep Kumar and K. A. Suresh, *Colloids and Surfaces A: Physicochem. Eng. Aspects*, **410**, 91 (2012)
5. Patterned flexoelectric instability in a bent-core nematic liquid crystal, Pramod Tadapatri, K. S. Krishnamurthy and W. Weissflog, *Soft Matter*, **8**, 1202 (2012).
6. Triazole-modified triphenylene derivative: self-assembly and sensing applications, Vandana Bhalla, Hardev Singh, Manoj Kumar, and S. Krishna Prasad, *Langmuir*, **27**, 15275 (2011).
7. Behavior of thermo-optical, dielectric and elastic constants of azo-dye doped nematic liquid crystals as photosensitive flexoelectric soft materials, S. Sridevi, U. S. Hiremath, C. V. Yelamaggad, S. K. Prasad, Y. G. Marinov, G. B. Hadjichristov, and A. G. Petrov, *Mater. Chem. Phys.*, **130**, 1329 (2011).
8. Self-assembly of chiral hexacatenar-bisamides into a columnar structure, G. Shanker, D. S. Shankar Rao, S. Krishna Prasad and C. V. Yelamaggad, *RSC Advances*, **2**, 1592 (2012)
9. New photoactive guest-host nematics showing photoflexoelectricity, A. G. Petrov, Y. G. Marinov, G. B. Hadjichristov, S. Sridevi, U. S. Hiremath, C. V. Yelamaggad, and S. K. Prasad, *Mol. Cryst. Liq. Cryst.*, **544**, 3/[991] (2011).

10. Thermo-optical study of azo-dye doped nematic liquid crystals as flexoelectric guest-host systems, Y. G. Marinov, G. B. Hadjichristov, A. G. Petrov, S. Sridevi, U. S. Hiremath, C. V. Yelamaggad, and S. K. Prasad, *Compt. Rend. Acad. Bulg. Sci.*, **64**, 669 (2011).
11. Enhanced Frank elasticity and storage modulus in a diamagnetic liquid crystalline ferrogel, R. Bhargavi, Geetha G. Nair, S. Krishna Prasad, Nitesh Kumar and A. Sundaresan, *Soft Matter*, **7**, 10151 (2011).
12. High-pressure investigations of a ferroelectric liquid crystal exhibiting a trend reversal in the thermal variation of polarization, Prasad N. Bapat, D. S. Shankar Rao, S. Krishna Prasad, Jawad Naciri and B. R. Ratna, *J. Phys. Chem. B*, **115**, 10425 (2011)
13. Unsymmetrical cholesterol and benzoxazole-based liquid crystalline dimers: synthesis and characterization, K. C. Majumdar, T. Ghosh, D. S. Shankar Rao and S. Krishna Prasad, *Liquid Crystals*, **38**, 1269 (2011).
14. 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*, **14**, 606 (2011).
15. 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, *Liquid Crystals*, **38**, 615 (2011).
16. 2-phenylbenzoxazole-containing calamitic liquid crystals: synthesis and characterization, K. C. Majumdar, T. Ghosh, D.S. Shankar Rao and S. Krishna Prasad, *Liquid Crystals*, **38**, 625 (2011).
17. 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)
18. 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)
19. Non-conventional liquid crystals: synthesis and mesomorphism of non-symmetric trimers and tetramers derived from cholesterol, A. S. Achalkumar, U. S. Hiremath, D. S. Shankar Rao and C. V. Yelamaggad, *Liquid Crystals*, **38**, 1563 (2011). (Invited)
20. Synthesis and phase transitional behavior of dimer-like optically active liquid crystals, G. Shanker and C. V. Yelamaggad, *J. Phy. Chem. B*, **115**, 10849 (2011).
21. A new class of low molar mass chiral metallomesogens: synthesis and characterization, G. Shanker and C. V. Yelamaggad, *J. Mater. Chem.*, **21**, 15279 (2011).

22. Thermodynamic, optical and dielectric, properties of the twisted grain boundary phases of the *homologous series of 4-n-alkyloxy-4'-(cholesteryloxy-carbonyl-1-butyl-oxy)chalcone*, A. S. Pandey, R. Dhar, A. S. Achalkumar and C. V. Yelamaggad, *Liquid Crystals*, **38**, 775 (2011).
23. Electrical behaviour of twist grain boundary phases of 4-n-dodecyloxy-4'-(cholesteryloxy-carbonyl-1-butyl-oxy)chalcone, Abhay S. Pandey, R. Dhar, A. S. Achalkumar and C. V. Yelamaggad, *The Open Crystallography Journal*, **4**, 49 (2011).
24. NMR study of a phasid-like liquid crystal, A. Marini, M. Geppi, Veena Prasad and R. Y. Dong, *Chemical Physics Letters*, **507**, 96, (2011).
25. Anthraquinone-based discotic liquid crystals: new monomers and dimers, Veena Prasad, Arun Roy, N. G. Nagaveni and K. Gayathri, *Liquid Crystals*, **38**, 1301 (2011).
26. Room temperature columnar phase: Influence of 2-ethylhexane peripheral chain on the mesomorphism of polyalkynylbenzene based disc – shaped molecules, Sanjay K. Varshney, H. Nagayama, Veena Prasad and H. Takezoe, *Liquid Crystals*, **38**, 1321 (2011).
27. Twist disclination loops in a bent-core nematic liquid crystal, K. S. Krishnamurthy, Pramod Tadapatri and W. Weissflog, *Soft Matter* **7**, 6273 (2011).
28. On the magnetic ground state of La<sub>0.85</sub>Sr<sub>0.15</sub>CoO<sub>3</sub> single crystals , Manna Kaustuv; Samal Debakanta; Elizabeth Suja; H. L. Bhat and P. S. AnilKumar, *J. Phys. Chem. C*, **115**, 13985 (2011)

### In press

1. Confinement driven effects in a room temperature ferroelectric liquid crystal: X-ray, linear and non-linear dielectric investigations, M. Vijay Kumar, S. Krishna Prasad, D.S. Shankar Rao and E. P. Pozhidaev, *Phase Transitions* (in press).
2. Effect of hydrostatic pressure on the Frank splay and bend elastic constants, Prasad N. Bapat, D. S. Shankar Rao, S. Krishna Prasad and Uma S. Hiremath, *Thermochimica Acta*, (in press).
3. Bend flexoelectricity of a polymorphic mesogen, S. Sridevi, Uma S. Hiremath, C.V. Yelamaggad, A. G. Petrov, S. Krishna Prasad, *Bulg. J. Phys* (in press)
4. Influence of polar substituents on the mesomorphism of non-symmetrical achiral four-ring bent-core compounds: synthesis and characterization, R. K. Nath, D. D. Sarkar, D. S. Shankar Rao and N. V. S. Rao, *Liquid Crystals* (in press)
5. Anomalous dielectric behavior in the nematic and isotropic phases of a strongly polar-weakly polar binary system, M. Sarvamangala, M. Vijay Kumar, S.M. Khened, S. Basavaraja, D. S. Shankar Rao and S. Krishna Prasad, *Phase Transitions* (in press).

6. Achiral bent-core azo compounds: effect of different types of linkage groups and their direction of linking on liquid crystalline properties, N. G. Nagaveni, Arun Roy and Veena Prasad, *J. Mater. Chem.* (in press).
7. Enhanced magnetic properties of chemical solution deposited BiFeO<sub>3</sub> thin film with ZnO buffer layer, R. Rajalakshmi, Nagaiah Kambhala, S. Angappane, *Materials Science and Engg. B* (2012)

### Publications in Conference Proceedings

1. Anomalously large bend elastic constant and faster electro-optic response in soft glassy gels formed by a dipeptide, Geetha G. Nair and R. Bhargavi, *Solid State Phenomena*, **181-182**, 14-21 (2012).
2. Studies on field dependent domain structures in multi-grained 0.85PbMg<sub>1/3</sub>Nb<sub>2/3</sub>O<sub>3</sub>–0.15PbTiO<sub>3</sub> thin films by scanning force microscopy, D. Saranya, Neena S. John, J. Parui & S. B. Krupanidhi, *Integrated Ferroelectrics: An International Journal*, **134:1**, 39-47 (2012).
3. Magnetic properties of BiFeO<sub>3</sub> with ZnO buffer layer, R. Rajalakshmi, Nagaiah Kambhala and S. Angappane, *AIP Conference Proceedings*, **1451** (in press) [Indian Vacuum Society Symposium on Thin Films: Science & Technology, November 09-12, 2011, Bhabha Atomic Research Center, Mumbai.]
4. Synthesis of BiFeO<sub>3</sub> thin films by chemical solution deposition – structural and magnetic studies, Nagaiah Kambhala and S. Angappane, *AIP Conference Proceedings*, **1451** (in press) [Indian Vacuum Society Symposium on Thin Films: Science & Technology, November 09-12, 2011, Bhabha Atomic Research Center, Mumbai.]

### Papers & posters presented at the conferences

- 1) *Twist Disclination Loops in a Bent-Core Nematic Liquid Crystal*, Pramod Tadapatri, Poster presented at the Soft Matter Chemistry Workshop held at Raman Research Institute, Bangalore during 9-11 November 2011
- 2) *Magnetic Properties of BiFeO<sub>3</sub> with ZnO Buffer Layer*, R. Rajalakshmi, Nagaiah Kambhala and S. Angappane, Poster presented in Indian Vacuum Society Symposium on Thin Films: Science & Technology at Bhabha Atomic Research Center, Mumbai during 09-12 Nov 2011.
- 3) *Synthesis of BiFeO<sub>3</sub> Thin Films by Chemical Solution Deposition – Structural and Magnetic Studies*, Nagaiah Kambhala and S. Angappane, Poster presented in Indian Vacuum Society Symposium on Thin Films: Science & Technology at Bhabha Atomic Research Center, Mumbai during 09-12 Nov 2011.
- 4) *X-ray, linear and non-linear dielectric measurements on a ferroelectric liquid crystals in a confined geometry*, M.Vijay Kumar, Poster presentation at the 18<sup>th</sup> National Conference on Liquid Crystals held at Itanagar, Arunachal Pradesh, during 15-17

November 2011.

- 5) *Enhanced Frank Elasticity and Storage Modulus in a Diamagnetic Liquid Crystalline Ferrogel*, Ms. R. Bhargavi, Poster presentation at the 18<sup>th</sup>National Conference on Liquid Crystals held at Itanagar, Arunachal Pradesh, during 15-17 November 2011.
- 6) *New class of low molar mass liquid crystals: Synthesis and thermal behaviour of achiral dimer-like compounds*, Ms. Rashmi Prabhu, Poster presentation at the 18<sup>th</sup>National Conference on Liquid Crystals held at Itanagar, Arunachal Pradesh, during 15-17 November 2011.
- 7) *Photochromic phasmid-like liquid crystalline materials with unusual mesomorphic behaviour*, N. G. Nagaveni, Arun Roy and Veena Prasad, Poster presentation at the 18<sup>th</sup>National Conference on Liquid Crystals held at Itanagar, Arunachal Pradesh, during 15-17 November 2011.
- 8) *Studies on multi-valent ion interaction with mesogenic amphiphilic molecules at the air-water interface*, T. Shilpa Harish, Poster presentation at the 18<sup>th</sup>National Conference on Liquid Crystals held at Itanagar, Arunachal Pradesh, during 15-17 November 2011.
- 9) *Studies on Langmuir-Blodgett films of alternate layers of stearic acid and its mixture with octyl-cyanobiphenyl using atomic force microscopy*, H.N.Gayathri, Poster presentation at the 18<sup>th</sup>National Conference on Liquid Crystals held at Itanagar, Arunachal Pradesh, during 15-17 November 2011.
- 10) *Luminescent columnar liquid crystals derived from s-triazine core: molecular design, synthesis and characterization*, Hashambi K.Dambal, Poster presentation at the 18<sup>th</sup>National Conference on Liquid Crystals held at Itanagar, Arunachal Pradesh, during 15-17 November 2011.
- 11) *Studies on assembly of molecules in Langmuir-Blodgett films of cholesteryl derivatives*, K. R. Vinaya Kumar, Poster presentation at the 18<sup>th</sup>National Conference on Liquid Crystals held at Itanagar, Arunachal Pradesh, during 15-17 November 2011.
- 12) *Interfacial rheology studies on multi-valent ion interactions with mesogenic amphiphilic molecules*, T. Shilpa Harish, Poster presentation at the SERC School and Symposium on Rheology of Complex Fluids held at IIT-Guwahati, Assam, during January 3-7 2012.

**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](mailto:admin@csmr.res.in)**

**Website: <http://www.csmr.res.in>**

**मृदु पदार्थ अनुसंधान केंद्र**

**डाक बॉक्स १३२९**

**प्रो। यू. आर. राव मार्ग**

**जालहल्ली**

**बेंगलूरु – ५६० ०१३**

**फोन: 080-2838 6582, 2838 1119, 2838 1347, 2838 2337, 2345 6403**

**टेलीफ़ैक्स : 080-2838 2044**

**ईमेल : [admin@csmr.res.in](mailto:admin@csmr.res.in)**

**वेब : <http://www.csmr.res.in>**