नैनो एवं मृदु पदार्थ विज्ञान केंद्र

विज्ञान एवं प्रौद्योगिकी विभाग, भारत सरकार के अधीन एक स्वायत्त संस्था

CENTRE FOR NANO AND SOFT MATTER SCIENCES

Autonomous Institute under the Dept. of Science and Technology, Govt. of India

वार्षिक रिपोर्ट
२०१४-१५

Annual Report
2014-15

CENTRE FOR NANO AND SOFT MATTER SCIENCES

BENGALURU

नैनो एवं मृदु पदार्थ विज्ञान केन्द्र

बेंगलूरु

ANNUAL REPORT

2014 – 2015

वार्षिक रिपोर्ट

2014 – 2015

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(One vacancy has arisen on account of Prof. Ashutosh Sharma's assumption of charge as Secretary, DST.)

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CONTENTS

PAGE NO.

FOREWORD

1. INTRODUCTION 1
2. CORE FUNDED PROJECT 1-2
3. RESERVATION AND OFFICIAL LANGUAGE 2-3
4. RESEARCH AND DEVELOPMENT ACTIVITIES 3-31
5. SPONSORED PROJECTS 31-33
6. WOMEN'S DAY 33
7. NATIONAL SCIENCE DAY 33-38
8. PROF. S. CHANDRASEKHAR MEMORIAL LECTURE 39-41
9. STUDENTS' PROGRAMME 41-43
10. POPULARIZATION OF SCIENCE 43-44
11. VISITS ABROAD AND TALKS GIVEN 44
12. SEMINARS / TALKS GIVEN AT OTHER INSTITUTES 45-47
13. LECTURES BY VISITORS 47-49
14. AWARDS / HONORS 49
15. LIST OF SCIENTISTS AND RESEARCHERS 49-50
16. ADMINISTRATIVE STAFF 50-51
17. PUBLICATIONS DURING 2014-2015 51-54
18. STATEMENT OF ACCOUNTS AND BALANCE SHEET 55-67

FOREWORD

The Centre for Soft Matter Research (CSMR) widened the scope of research activity to embrace Nano Science and Technology , following the decision of the Department of Science and Technology to entrust the responsibility of setting up a Centre of Excellence, encompassing research in new and emerging fields of nano science and technology, along with soft matter.

The Centre has thus come to be known as Centre for Nano and Soft Matter Sciences (CeNS) from 1 April, 2014. The Centre will be mentored by Nano Mission of the Government of India.

The Centre has already embarked on collaborative activity with well-known industries. Many innovative programmes for popularization of science have also been conducted. The Centre plans to introduce internship programmes and to enroll more students for research programmes, leading to PhD, in the area of nano science and technology.

The Centre aims to achieve high growth and bring in innovations for the benefit of society at large through science, in the coming years.

DIRECTOR

1. INTRODUCTION

The Centre for Nano and Soft Matter Sciences (CeNS) is an autonomous research institute under Department of Science and Technology (DST), Government of India. DST provides core support to the Centre in the form of a grant-in-aid for conducting basic and applied research in nano and soft matter sciences. CeNS is located at Jalahalli, Bengaluru.

The Centre is engaged in materials research at all relevant length scales. Specifically, the current activities are focussed on a variety of metal and semiconductor nanostructures, liquid crystals, gels, membranes and hybrid materials. It has close interactions with many Institutions and Industry, in India and abroad.

The Centre was established in 1991 by an eminent liquid crystal scientist, Prof. S. Chandrasekhar, FRS. It was then known as Centre for Liquid Crystal Research, a registered scientific society in Karnataka with the objective to build a centre of excellence in line with the international trend those days on liquid crystal materials and devices. In 1995, it became an autonomous institute under the Department of Electronics (DOE), Government of India and in 2003, was brought under DST. Subsequently in the year 2010, the name was changed to Centre for Soft Matter Research. Recently in 2014, the Centre has further widened the scope of research activities to embrace nanoscience and technology and is now known as Centre for Nano and Soft Matter Sciences (CeNS). It is being mentored by Nano-Mission of the Government of India.

With the expended responsibility, the Centre has renewed its vision to work in pursuit of Global excellence in Science and to nurture Indigenous Technology for the betterment of Our Country.

2. CORE FUNDED PROJECT

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

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

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

* During the year 2014-15, a grant of Rs. 511.67 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 12 September 2014. On this occasion, Dr. V.Thilagam, Indian Institute of Science, Bengaluru gave a lecture entitled कार्यान्वयन में वैज्ञानिक एवं तकनीकी शब्दावली आयोग की भूमिका.

Dr. V.Thilagam, Indian Institute of Science, Bengaluru, delivering a talk.

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

4. RESEARCH AND DEVELOPMENT ACTIVITIES

4.1 *ENHANCEMENT OF ELECTRICAL CONDUCTIVITY OF A LIQUID CRYSTAL-GOLD NANOPARTICLE COMPOSITE BY A NETWORK OF INSULATING PARTICLES*

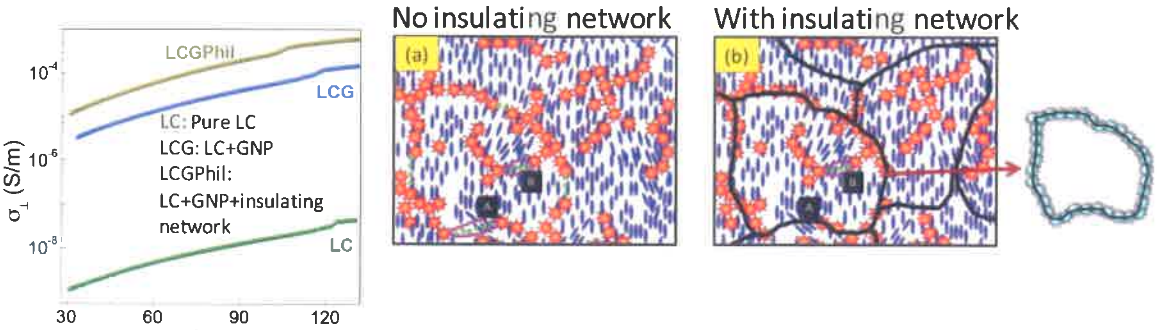


Figure 1

We have demonstrated that a network of insulating aerosil particles can have a strong influence on the magnitude of the electrical conductivity of a nematic liquid crystal composite (LCG) comprising GNPs, increasing it beyond the values achieved by the metal particles. Calorimetry brings out the ability of the two types of nanoparticles, having comparable size and spherical shape to influence the disorder in the system by different magnitudes. The gel network resulting in a large bulk viscosity of the medium forces the frequency behavior of the system to conform to the expectations for disordered solids, despite the presence of the confined liquid. The nature of the aerosil corona (hydrophobic/hydrophilic) provides tunability factor for the H-bonding, and influences the magnitude as well as the frequency dependence of conductivity. We propose an argument that these features are caused by the repair of the "dead bonds" in the percolation network by the imposed gel network of aerosil particles, extending the path for the charge transport (Figure 1). Such a possibility opens up an avenue to tune the conductivity by controlling the strength of the gel. The methodology is easily amenable to generalization for a variety of systems involving metal particles embedded in an insulating matrix. Since these types of gels have the capability to be self-supporting, free standing conducting systems as well as patternable motifs can be realized. The frequency spectrum of conductivity again follows the universal behaviour. The deviation in the exponent from the universal value diminishes, upon adding GNP. Interestingly, the exponent attains the universal behaviour when the insulating H-bonded network is imposed.

This work has been published: *Appl. Phys. Lett.,* **106**, 083110 (2015)

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

4.2 *PHOTO-DRIVEN GIANT REDUCTION OF THE FRANK ELASTIC CONSTANTS IN A BENT-CORE NEMATIC LIQUID CRYSTAL*

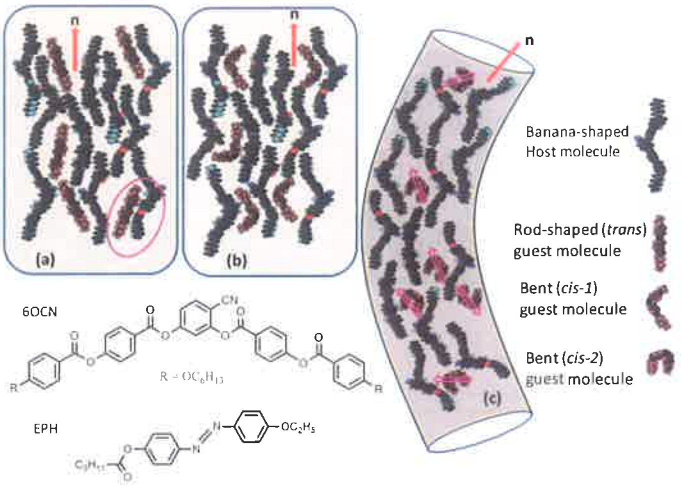


Figure 2

The influence of photoisomerization on the Frank elastic constants of a mixture consisting of a bent-core nematic host and a photoactive guest compound has been investigated. Both the splay and bend elastic constants exhibit drastic photo-driven softening in addition to weakened temperature dependence of the latter parameter. Interestingly, the ratio of the splay to the bend elastic constant (K_{33}) increases indicates a large favour by the system towards retaining a bend deformation. These features which are reversible can be explained using conformational changes and the molecular packing (Figure 2). The ability to lower K_{33} by an external means has important ramifications. Several properties, such as low bend/splay ratio and low dielectric anisotropy (normalized to permittivity), desirable for multiplexing of twisted nematic liquid crystal device (TN-LCD), are exhibited in the photo-driven state by the present system. It is also observed that photoisomerization has minimum influence on the rotational viscosity, another useful feature for display devices. The large reduction, especially in the bend elastic constant, points towards an attractive route to realize the currently sought-after twist-bend nematic phase.

This work has been published: *Appl. Phys. Lett.,* **104**, 241111 (2014).

Investigators: P. Lakshmi Madhuri, S. Krishna Prasad, Uma S. Hiremath, and C. V. Yelamaggad

4.3 NANOPHASE SEGREGATION OR LAYER ROUGHENING?: MINORITY GOVERNS THE PACKING IN A N-ALKANE – LIQUID CRYSTAL BINARY SYSTEM

Two important features that arise out of introducing a liquid crystalline (LC) compound into the rotator phase matrix, and the consequent competition between the anisometric segments of the LC moieties, and the aliphatic units have been demonstrated. First, we show that the change in the structural character of the mixed medium depends on which of the entities forms the minority concentration: in case of this being the alkane, the two components of the binary system get nanophase segregated, whereas if the LC molecules are in small concentration then the layered structure merely gets roughened without any segregation (Figure 3). The second and more significant result of the calorimetric and Xray experiments, at low LC concentrations, is the induction of a rotator phase that leads to unusual phase sequence, not reported hitherto. Possible scenarios for the molecular arrangement are discussed. A Landau model is also presented that explains some of the observed features. The fact that an anisometric molecule can induce a rotator phase with high disorder perhaps indicates that this route can be employed to increase the richness of features seen in alkane systems, e.g., observation of the condis phase.

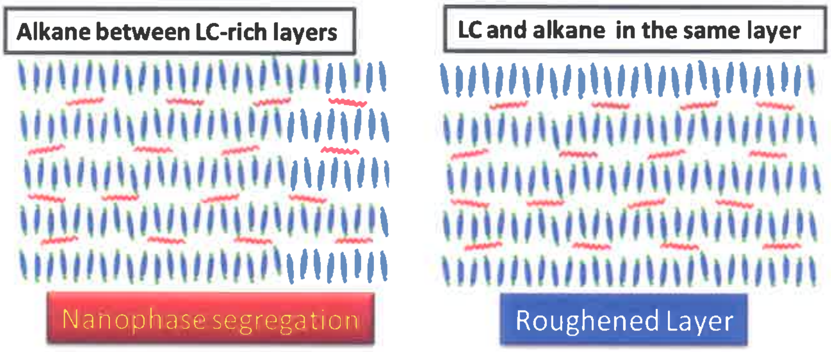


Figure 3

This work was carried out in collaboration with P.K. Mukherjee from College of Engineering and Textile Technology, Hoogly and has been published : *Langmuir*, **30**, 4465 (2014).

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

4.4 A CHARGE TRANSFER COMPLEX NEMATIC LIQUID CRYSTALLINE GEL WITH HIGH ANISOTROPIC ELECTRICAL CONDUCTIVITY

The rheological, dielectric and elastic properties of a nematic liquid crystal gel created using a chiral triterpenoid, obtained from the extracts of the wood of Terminalia arjuna are reported. In this novel gel, having the electron-donor and electron-acceptor components as minority constituents, the gelation and charge-transfer (CT) complex formation are seen to be occurring concomitantly.

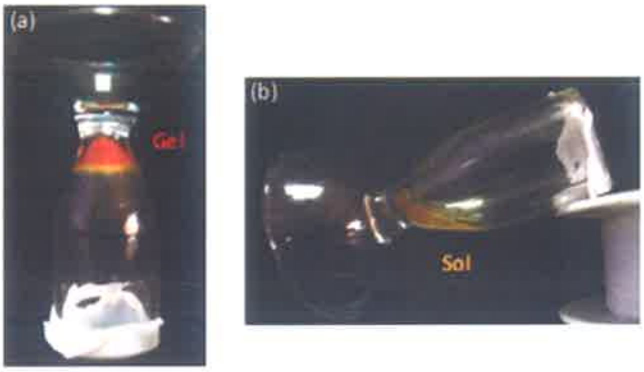


Figure 1: The immobility of the deep orange coloured CT gel and the free flow in the sol state are evident from the photographs (a) and (b) respectively

In addition to being mechanically strong with a large storage modulus, the gel with the maximized CT complex exhibits Frank bend elastic constant values that approach nano-newton levels.

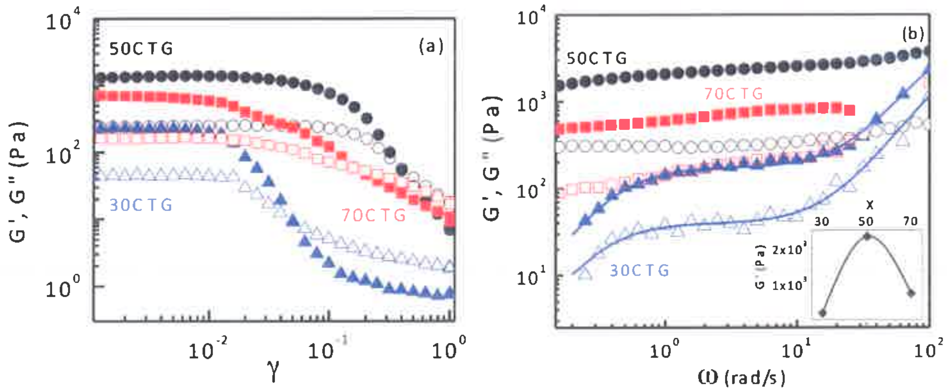


Figure 2: *(a) Strain and (b) angular frequency dependence of storage (G': solid symbols) and loss (G" :open symbols) moduli at T=25°C for different composites. The concentration dependence of the G' is shown in the inset to (b). The CT complex with 1:1 molar ratio (50CTG) of electron donor and acceptor molecules has the highest elastic modulus value.*

The highlight of the study is the observation of 4-5 orders of magnitude increase in electrical conductivity for this gel, a value that is even higher than in the CT complexes of 2-d ordered columnar structures. An important advantage of the present system over the columnar one is that the high conductivity is seen for ac probing also, and owing to the nematic nature can be switched between its anisotropic limits. Some of these features are ascribed to a specific molecular packing architecture, which reduces the trapping of the charge carriers.

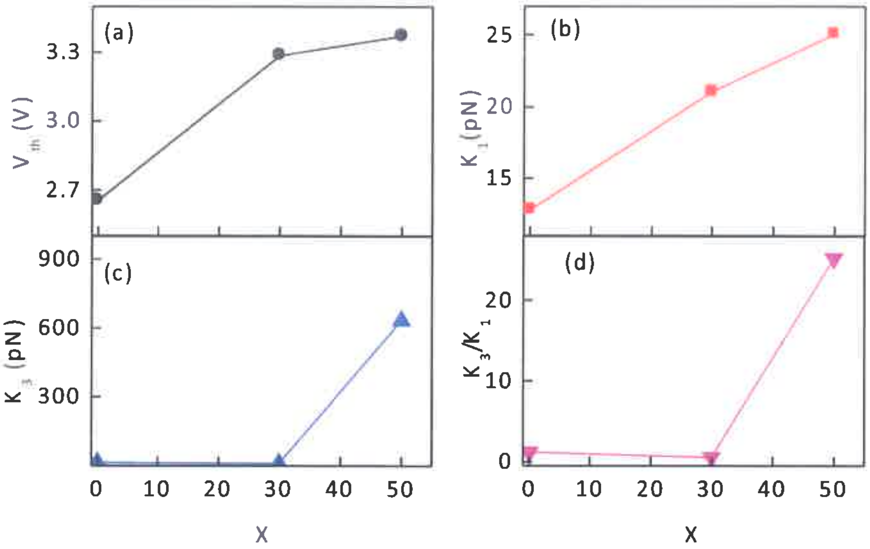


***Figure 3**: Influence of the molar ratio of AA : PA in the composites on the (a) threshold voltage (V_{th}), (b) the splay (K_1) and (c) the bend (K_3) elastic constants and (d) their ratio.*

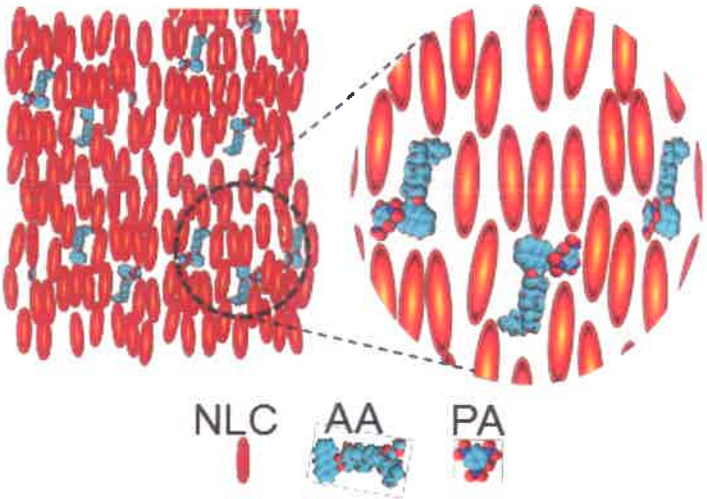


***Figure 4**: Possible molecular packing in the 50CTG composite rendering specifically the disposition of the AA and PA molecules so as to maximize the conductivity as well as to retain an efficient charge transfer.*

This work was carried out in collaboration with Braja G. Bag and R. Majumdar (Vidyasagar University, Midnapore) and has been published: *J. Appl. Phys.* **116**, 154902 (2014).

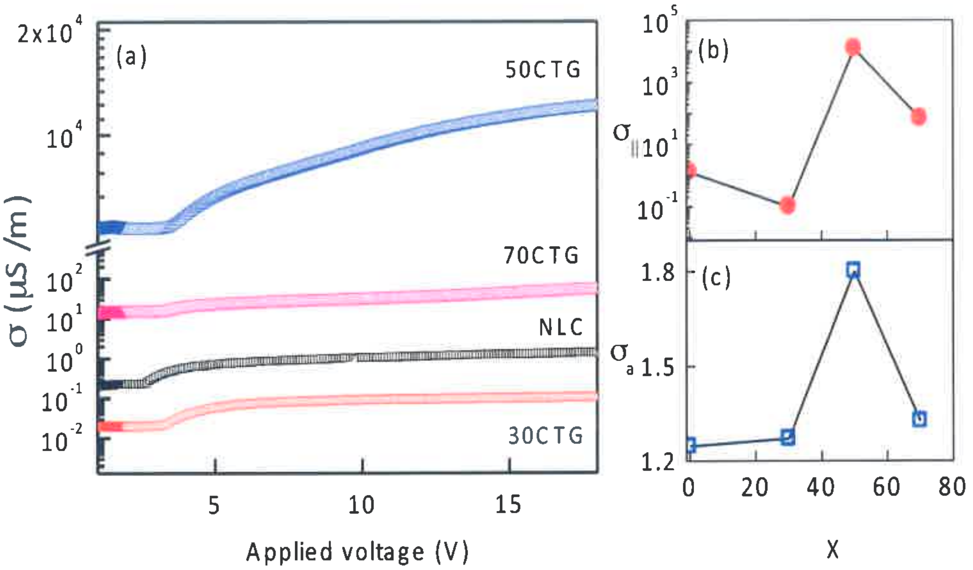


Figure 5: *(a) Conductivity (σ) vs applied voltage (V) for NLC and CT gels. The limiting values at the low and high voltage sides correspond to $\sigma_{\parallel}$ and $\sigma_{\perp}$ respectively. (b) $\sigma_{\parallel}$ for NLC and the three composites showing the value to be highest in the case of 50CTG. (c) The ratio of $\sigma_{\parallel}$ and $\sigma_{\perp}$ gives the conductivity anisotropy (σ_a), whose concentration dependence is shown. The anisotropy also is the highest for 50CTG.*

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

4.5 VISCOELASTIC INVESTIGATIONS ON A BINARY SYSTEM OF STRONGLY POLAR BENT-CORE AND ROD-LIKE NEMATIC LIQUID CRYSTALS

The viscoelastic properties of the nematic medium control to a large extent both the static and dynamic response of the display devices. Apart from the application point of view, the studies on bent core nematics (BCNs) are of fundamental importance to gain a better understanding of the influence of the deviation in the shape, and possible polar order on viscoelastic coefficients, the order parameter and its fluctuations. The features considered generally true for the well-studied rod-like nematics (RLNs), are not applicable in the case of BCNs: $K_{11} < K_{33}$ for RLN, but the opposite ($K_{11} > K_{33}$) is almost always true for BCNs, rotational viscosity for BCNs is much larger than the values for the RLNs, etc. Here we describe a detailed study of the viscoelastic coefficients in a BCN-RLN binary system in which both the constituents are pure nematogens, and none of the mixtures exhibiting any other mesophase.

Experiments have been carried out on various concentrations (X wt%) of BCN in RLN. The electric field driven Freedericksz transition of a planar oriented sample was employed to determine the elastic constants. For the extraction of the elastic constants from the capacitance- voltage profiles were employed. Results show that the dielectric anisotropy increases monotonically with increasing X. The thermal variation of e in the isotropic, as well the average value in the nematic phase, suggest the presence of substantial antiparallel interactions up to a sizeable dilution of the rod-like system. The relative magnitudes of the splay and bend elastic constant change over from the standard rod-like behaviour ($K_{11}< K_{33}$) to that often observed for bent-core materials ($K_{11}>K_{33}$) even at a surprisingly low (X=30%) content of the BCN compound. More surprisingly, certain intermediate mixtures exhibit a convex-shaped thermal variation of the K_{33}. We have demonstrated that the order parameter dependence of the elastic constants can be very well described by employing an expression, not used traditionally, involving third order terms.

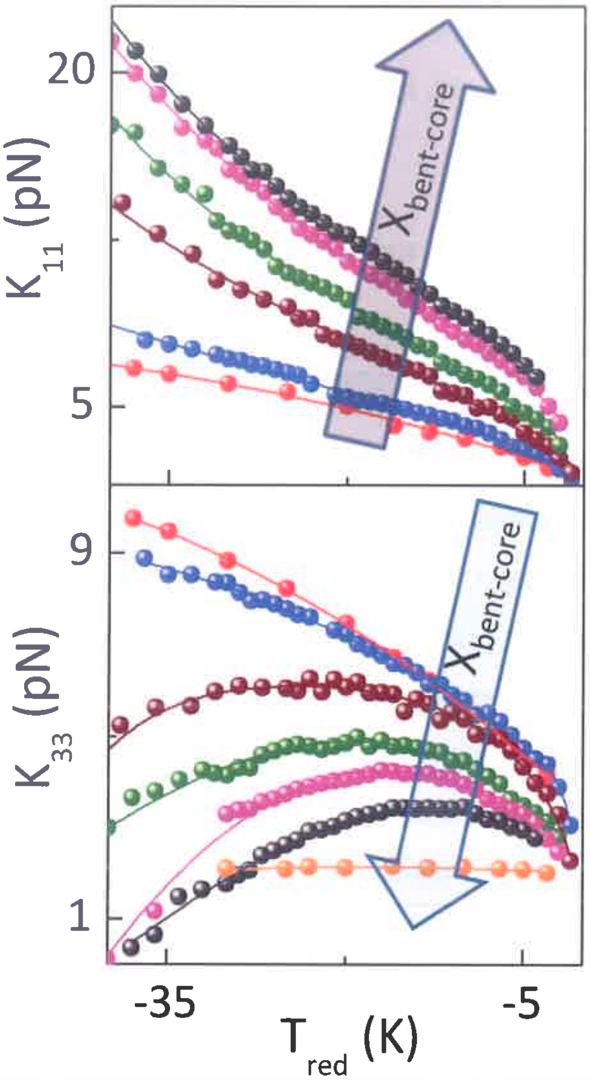


Fig. 1: Thermal variation of K_{11} & K_{33} for various X_{BCN}; there is significant increase in the value of K_{11} for intermediate X with the maximum occurring for higher value of X. K_{33} vs. X shows a convex shaped behaviour which is absent for pure compounds.

In conclusion the thermal dependence of both the splay and bend elastic constants exhibit features different from those reported in the literature. The results suggest that bent-rod mixtures are excellent candidates to tune the elastic anisotropy of the nematic medium, a feature of potential interest for display devices.

This work was carried out in collaboration with K. Fodor Csorba from Wigner Research Centre for Physics, Institute for Solid State Physics and Optics of the Hungarian Academy of Sciences, Post Office Box 49, H-1525 Budapest, Hungary. This work has been published: Srividhya Parthasarathi, D. S. Shankar Rao, K. Fodor Csorba, and S. Krishna Prasad, *J. Phys. Chem. B,* **118**, pp 14526–14535 (2014).

Investigators: Srividhya Parthasarathi, D. S. Shankar Rao and S. Krishna Prasad

4.6 SUPERGELATION VIA PURELY AROMATIC π-π DRIVEN SELF-ASSEMBLY OF PSEUDODISCOTIC OXADIAZOLE MESOGENS

The physical properties of oxadiazole-based stilbene molecules have been examined using various experimental tools. Xray diffraction studies has revealed that lower members of the series form smectic phase whereas the longer alkyl chain members form columnar mesophase. More interestingly they show a transition from columnar phase with 2-dimensional hexagonal lattice to an oblique columnar phase. The higher member of the series showed a strong tendency to form aggregates in solutions forming stable gels in organic solvents. The gels are with unusually high thermal and mechanical stability, could be ascribed to the combined effect of aromatic π–π stacking and the columnar arrangement of molecules in the gel fibers. The structure of the dry gel investigated using XRD showed clear indicative of a columnar arrangement of the molecules within the nanofibers.

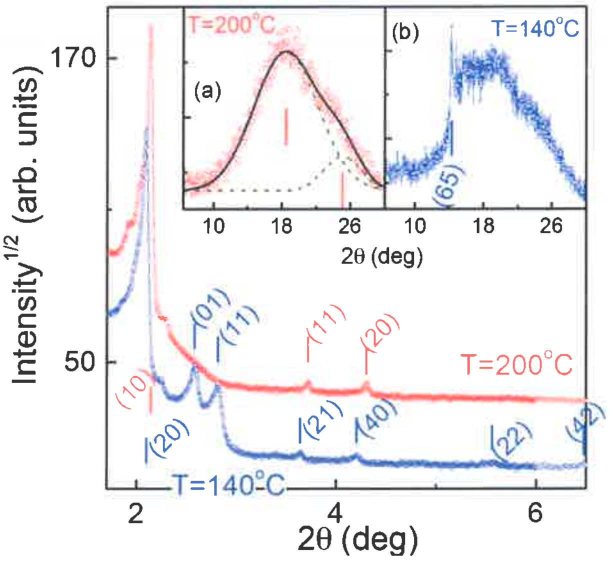


***Figure** 2: XRD scan of higher member of the series in the high temperature col$_h$ and low temperature col$_{ob}$ phase along with (hkl) indexing. The inset depicts the wide angle region of the diffraction pattern. The inset depicts the wide angle region of the diffraction pattern.*

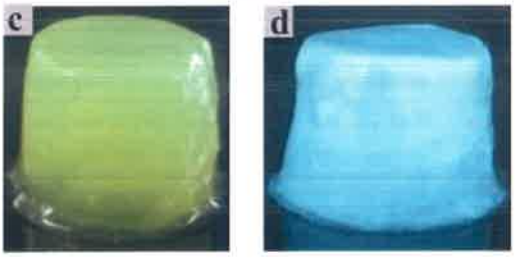


***Figure** 3: Photographs of the gel at room temperature under normal light (left) and UV (λ = 365 nm) illumination (right).*

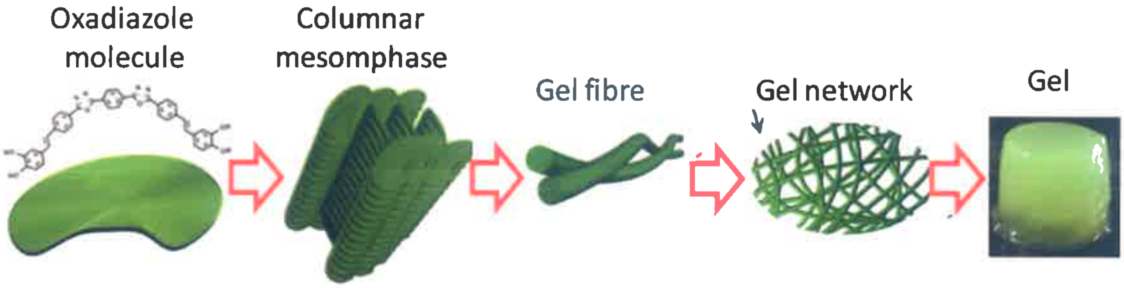


Figure 4: *Schematic Representation for the Hierarchical Formation of the Self-Standing Gel*

This work was carried out in collaboration with Suresh Das, Photosciences and Photonics Section, Chemical Sciences and Technology Division, NIIST and Network of Institutes for Solar Energy, CSIR, Trivandrum 695 019 India. This work has been published: *J. Am. Chem. Soc.,* **136**, 5416–5423 (2014).

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

4.7 BENT-CORE NEMATOGENS

The bent-core nematogens gain importance due to their potential to form ferroelectric and biaxial nematic liquid crystals. Both these liquid crystals are important from the display application point of view. They also exhibit unusual properties like chiral domains and electro-convection patterns which we normally do not see in classical nematic liquid crystals.

In 2005, we reported two bent-core nematogens exhibiting a very unusual nematic behaviour, which triggered the investigations on biaxial nematic liquid crystals around the world. However, due to their high transition temperatures these nematogens were not all that suitable for physical studies. Therefore, to overcome this problem, we synthesised different series of bent-core compounds with lateral substituents. All these compounds are made up of non-symmetrical molecules and we observed that the transition temperatures were reduced significantly due to the lateral substitution. The liquid crystalline properties of these compounds were initially studied by using POM and DSC. The molecular organisations in different mesophases were investigated by XRD studies and the unusual properties of N mesophases were investigated by E-O studies.

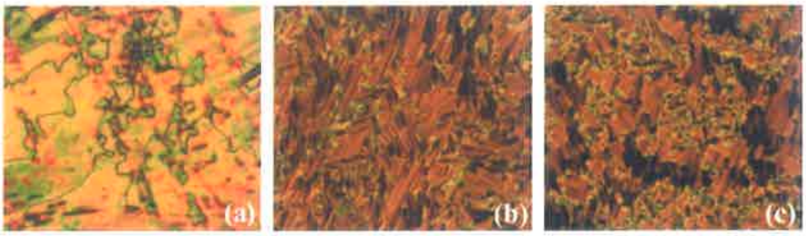


Figure: POM textures for one of the compound (6.D.18), obtained on cooling from the isotropic liquid: (a) thread-like texture of N mesophase at 135°C, (b) focal-conic texture of SmA mesophase at 105°C and (c) unspecified texture of SmX_1 *mesophase at 90°C.*

On applying an electric field to the planar oriented N mesophase of these samples, they formed electro-convection patterns at high voltage and high frequencies, indicating the strong hydrodynamic instabilities in their N mesophase. This suggests that the mesophase is of negative dielectric anisotropy.

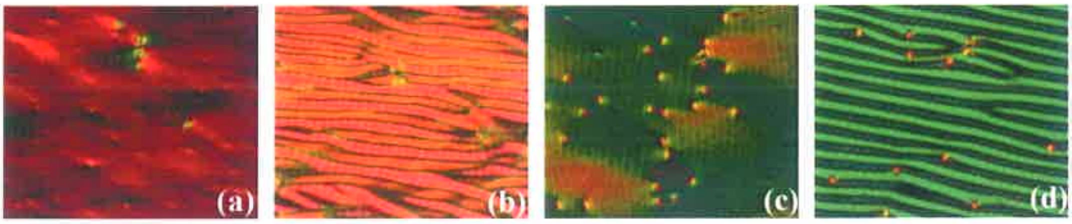


Figure: Field-induced textural changes of the nematic phase of one of the compound, 6.F.18 (a) 7.2 $V\mu m^{-1}$*, 130 Hz; (b) 9.8* $V\mu m^{-1}$*, 130 Hz at 125°C; (c) 7.2* $V\mu m^{-1}$*, 130 Hz and (d) 9.8* $V\mu m^{-1}$*, 130 Hz at 141°C.*

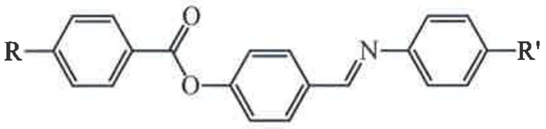
Since these compounds consist of -N=N- linkages, we performed a qualitative photo-induced studies on these compounds. We observed photosensitivity of these compounds both in their solution and nematic mesophase.

A manuscript is under preparation discussing all the above results in detail.

<u>Investigators:</u> N.G. Nagaveni and Veena Prasad.

4.8 DESIGNED, SYNTHESIZED AND CHARACTERIZED FIVE ENANTIOMERIC PAIRS OF THREE-RING CHIRAL LIQUID CRYSTALS (LCS).

(a)



R' = (*S*)-Octyloxy
1-(*S*)-8 : R = OC_8H_{17} ; **1-(*S*)-9** : R = OC_9H_{19} ; **1-(*S*)-10**: R = $OC_{10}H_{21}$;
1-(*S*)-11 : R = $OC_{11}H_{23}$; **1-(*S*)-12** : R = $OC_{12}H_{25}$
R' = (*R*)-Octyloxy
1-(*R*)-8 : R = OC_8H_{17}; **1-(*R*)-9** : R = OC_9H_{19}; **1-(*R*)-10**: R = $OC_{10}H_{21}$;
1-(*R*)-11: R = $OC_{11}H_{23}$; **1-(*R*)-12** : R = $OC_{12}H_{25}$

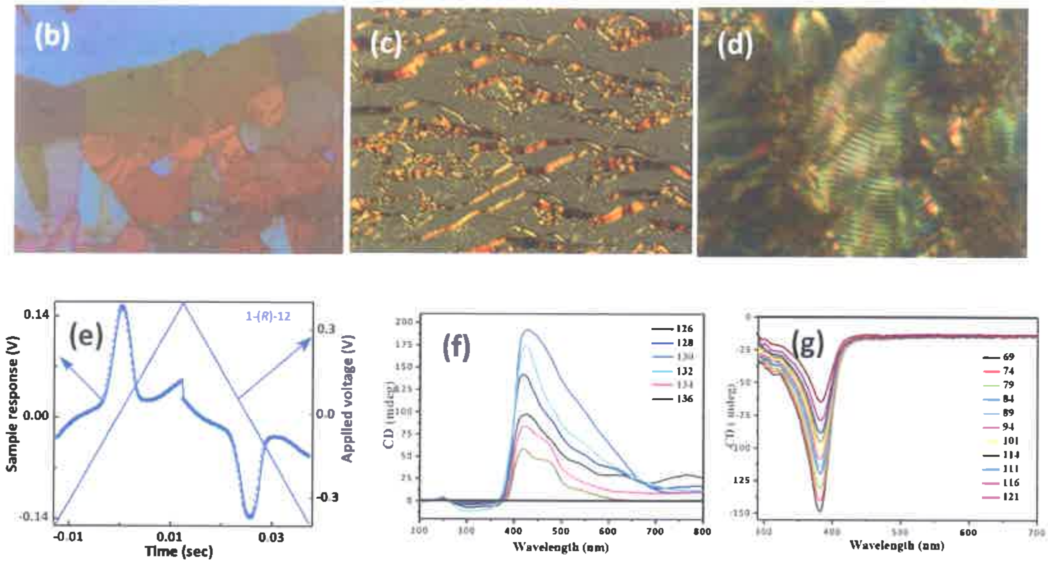


*Figure 1. (a) A general molecular structure of the mesogens synthesized. Microphotographs of the optical textural patterns of the mesophases of **1-(R)-10** : (b) The platelet texture of the BP-I/II; (c) the oily streak texture of the N* phase; (d) the fan-shaped texture with equidistant lines on top seen for the SmC* phase. (e) Switching current response peaks obtained upon applying a triangular-wave filed for the SmC* phase of **1-(R)-12**. (f) & (g) CD spectra obtained as a function of temperature in the N*(f) and SmC* (g) phases of enantiomer **1-(R)-9***

Five pairs of enantiomers (Fig. 1a) have been prepared and examined for mesomorphism and optical properties. Each pair of enantiomers consists of (*R*)-2-octyloxy and (*S*)-2-octyloxy chains at one end while the other terminus is substituted with an *n*-alkoxy tail. Thermal studies reveal an identical behavior of all the ten compounds implying that the alteration in the length of the *n*-alkoxy tail has no effect on the observed phase sequence such as BP-I/II (Fig. 1b) -N* (Fig. 1c) - SmC*(Fig. 1d) -SmX. However, the transition temperatures and thus, thermal width of the N* and SmC* phases show critical dependence on this variation. The temperature range of the SmC* phase widens when the length of the *n*-alkoxy chain increases. The presence of ferroelectric SmC* phase, over the thermal range of 20-55°C, has been established with the help of microscopic, calorimetric, XRD and electro-optical (Fig. 1e) studies; the calculated *Ps* value was found to be over 100 nC cm^{-2}. The CD spectra obtained for the thin films of the N* and SmC* phases of a pair of enantiomers exhibit an excellent mirror-image relationship indicating the opposite handedness of the macroscopic helices of the phases (Fig. 1f-g). The measurements confirm the opposite twist-sense of helices of the N* and SmC* phases of an enantiomer.

This work has been published: *New J. Chem.*, **39**, 2011-2027, 2015.

Investigators: B. N. Veerabhadraswamy, D. S. Shankar Rao, S. Krishna Prasad and C. V. Yelamaggad.

4.9 EFFECT OF CATIONS ON CONDENSATION OF A MESOGENIC AMPHIPHILIC MOLECULE AT THE AIR–AQUEOUS ELECTROLYTE INTERFACE

We report the interactions of a mesogenic molecule, 4′-octyl-4-biphenyl-carbonitrile (8CB), with some cations (Na^+, Cu^{2+}, Ni^{2+}, La^{3+} and Al^{3+}) dissolved in the aqueous subphase. Surface manometry studies show that the di- (Ni^{2+} and Cu^{2+}) and trivalent (La^{3+}) ions promote condensation in the area per molecule and enhance the stability of the monolayer (Fig. 1). This is inferred from the increase in the values of collapse pressure and the compression elastic modulus. The specific ion effect is seen between perchlorate and chloride anions with respect to the Al^{3+} cation. The presence of monovalent ions (Na^+) in the subphase does not influence the isotherm of 8CB. However, in this case, with pH (>6), the isotherm shifts to a higher area per molecule (Fig. 2). The excess Gibbs free energy calculated for the 8CB monolayer indicates repulsive interaction for monovalent ions and attractive interaction for multivalent ions in the subphase. Kinetic studies and ellipsometric adsorption isotherms indicate that multivalent ions perturb 8CB monolayer to a larger extent.

Our studies indicate that the interaction of ions with the 8CB monolayer at the air–electrolyte interface can be promoted by choosing cations of higher valency and anions of larger size, higher polarizability and chaotropic nature. These factors play an important role and can potentially affect the anchoring transition.

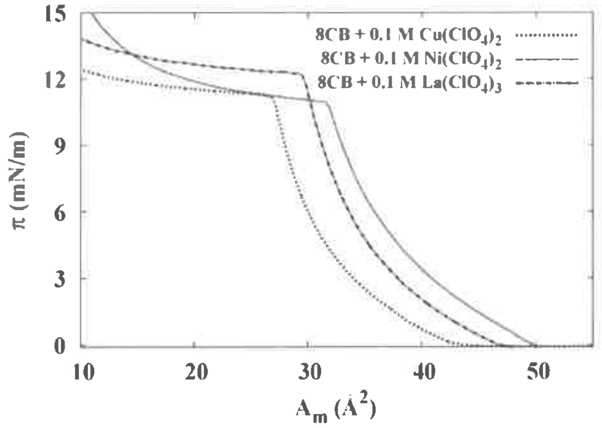


Fig. 1

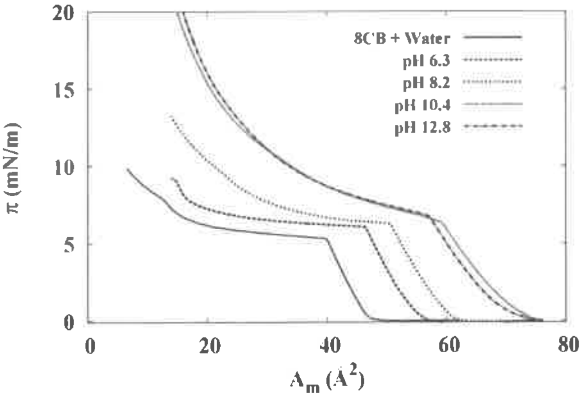


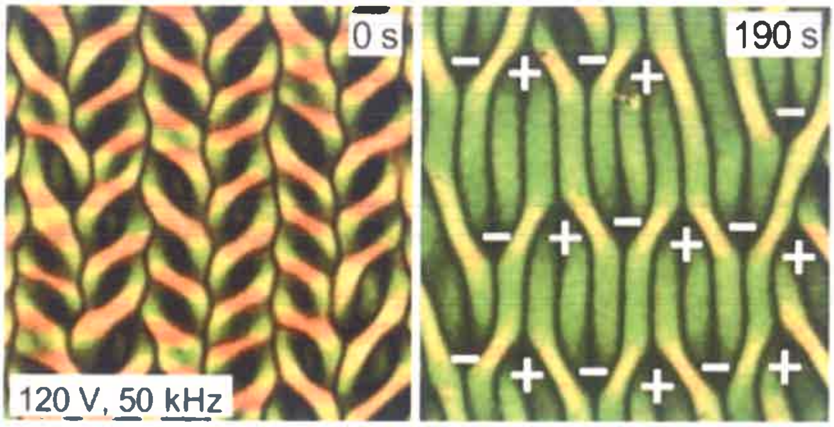
Fig. 2

This work has been published: Shilpa Harish T and P. Viswanath, ***Phys. Chem. Chem. Phys.***, **16**, 1276-1282 (2014).

Investigators: Shilpa Harish T and P. Viswanath

4.10 DISLOCATIONS AND METASTABLE CHEVRONS IN THE ELECTROCONVECTIVE IN-PLANE NORMAL ROLL STATE OF A BENT CORE NEMATIC LIQUID CRYSTAL.

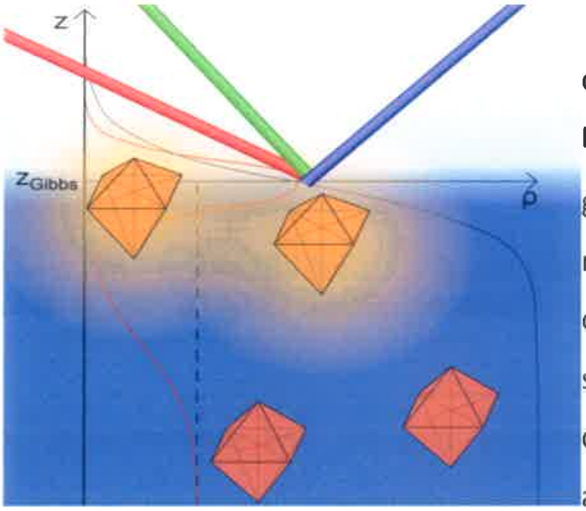
We report experimental results on the formation, dynamics, and annihilation of edge dislocations of opposite topological charge in the electroconvective inplane vortex state of a bent core nematic liquid crystal. The approach of paired, oppositely charged defects toward each other is a two-step process. Near constant velocity at large separation and accelerated motion close to annihilation are found, as in the case of nematic rolls belonging to standard electroconvection. Periodic arrays of dislocations of alternating polarity form upon a sudden, strong elevation of the control parameter. Chevron structures that appear between undulatory defect chains are metastable, and their decay with time is accompanied by an exponential reduction in the dislocation density. The initial periodicity of defect chains also drops exponentially with increasing field.



This work has been published: K. S. Krishnamurthy, P. Tadapatri and P. Viswanath, ***Soft Matter***, 10, 7316–7327 (2014).

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

4.11 BREAKING THE SYMMETRY OF IONS AT THE AIR–WATER INTERFACE



The impact of the fluid-air interface on the dissolved electrolyte potassium ferrocyanide $K_4[Fe(CN)_6]$ by infrared-visible sum-frequency generation spectroscopy (SFG) and surface tension measurements. SFG is a surface specific nonlinear optical technique that records the vibrational spectrum of the adsorbed species with little to no contribution from the bulk phase. Modes which are both Raman and Infrared active results in SFG signal. Since $[Fe(CN)_6]^{4-}$ belongs to the point group O_h, no vibrational mode is SFG active, unless a deformation leading to reduction in symmetry takes place. Our spectra provide experimental evidence for a symmetry reduction of the ions at the interface to subgroups with no center of inversion. The distortion of the ions is the direct consequence of the asymmetric environment at the interface and is further discussed in this paper. The SFG spectra of the interfacial water were used to gain further insights in the distribution of the ions at the interface. Furthermore, the combined data of the surface tension equilibrium isotherm and the SFG spectra suggest a non-monotonous interfacial concentration profile of the ion.

This work was carried out in collaboration with E. Brandes, Dr. P. Karageorgiev and Prof. Hubert Motschmann, University of Regensburg, Germany. This work has been published: E. Brandes, P. Karageorgiev, P. Viswanath and H. Motschmann, J. Phys. Chem. C, 118 (4), 26629–266233 (2014).

Investigator: P. Viswanath

4.12 RESISTIVE SWITCHING BEHAVIOUR OF RF MAGNETRON SPUTTERED ZnO THIN FILMS

This work involves the fabrication of Metal/ZnO/Pt device and study of resistive switching behaviour. The ZnO films were deposited on Pt/Si substrates by using RF magnetron sputtering and the top electrodes, such as, Cu, Al etc were deposited by DC sputtering. The

XRD data of our ZnO film shows the characteristic peak at 2θ value of 34.435, which is indexed to (002) plane. This confirms the formation of well crystallized ZnO films of hexagonal wurtzite structure with the oriented growth along *c* axis. The schematic diagram of a Cu/ZnO/Pt device fabricated for resistive switching studies is shown in figure 1(a).

The *I-V* characteristics were measured with the bottom Pt electrode grounded and the positive/negative bias applied to top Cu electrode. Typically, we observe a small hysteresis loop in the positive cycle and no switching is seen, as shown in figure 1(b). When the voltage is swept from 0 to −1 V in negative cycle, the current sharply jumps to lower values at around 0.6 V, which indicates the switching from LRS to HRS. During the next sweep in positive cycle, the device changes state from HRS to LRS, without sharp switching.

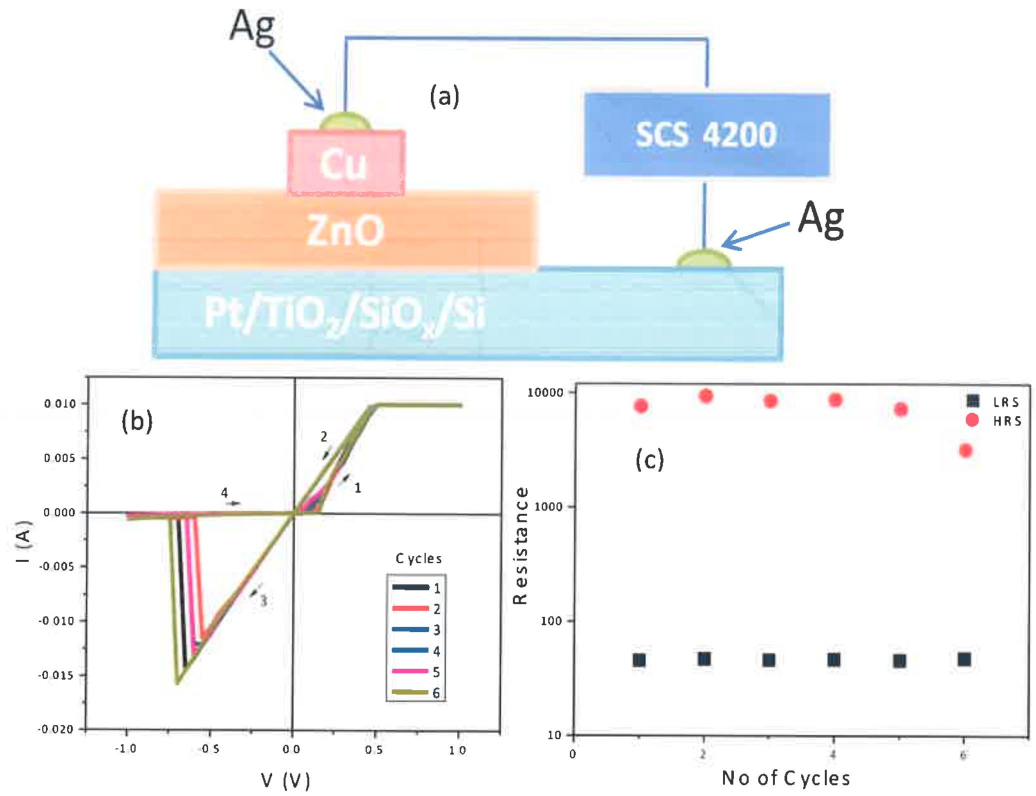


Fig. 1 (a) Schematic of Cu/ZnO/Pt device, (b) I-V characteristics and (c) Retention characteristics of our Cu/ZnO/Pt device.

With the negative bias at lower voltage regime, the device exhibits a Ohmic conduction which is due to the formation of filamentary conduction path generated out of oxygen vacancies from bottom electrode to the top electrode. At higher voltage regime, the switching from LRS to HRS is governed by Poole-Frenkel emission. The rupturing of the filaments occurs due to intense Joule heating. Figure 1(c) shows retention characteristics of our Cu/ZnO/Pt device read at –0.25 V, which indicates the HRS to LRS resistance ratio of ~ 200. We have observed resistive switching in ZnO thin film of thickness ~ 290 nm. However the HRS to LRS ratio was found to be one order less in case of thick ZnO films.

We have observed a sharp resistive switching at -0.4 V in Al/ZnO/Pt devices (Fig. 2). An electroforming upto -2.5 V is required for Al/ZnO/Pt device unlike Cu/ZnO/Pt device which does not require high voltage forming. In addition, we are also studying the stability of devices over period of time and understanding aging effect.

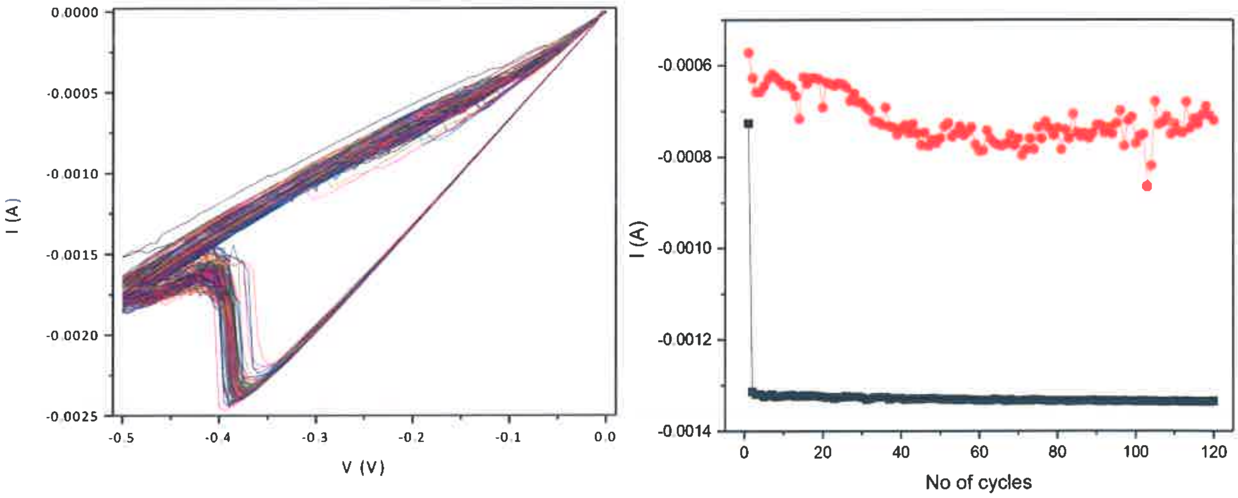


Fig. 2 I-V characteristics and (c) Retention characteristics of our Al/ZnO/Pt device.

These devices are expected to play a significant role in the memristive applications. Devices of different thickness and contact elements are being studied. A manuscript on this work is under preparation.

Investigators: R. Rajalakshmi, and S. Angappane

4.13 STUDY OF COEXISTING PHASES IN BI DOPED $La_{0.67}Sr_{0.33}MnO_3$

We study the remarkable phase separation behaviour in large bandwidth material, $La_{0.67}Sr_{0.33}MnO_3$ which is doped with Bi^{3+} ion at La site. The samples were prepared by standard solid state reaction route. $La_{0.67-x}Bi_xSr_{0.33}MnO_3$ samples show the rhombohedral structure up to x=0.3, while the XRD peaks split and changes shape for x ≥ 0.4, indicating the transition to orthorhombic structure. The structural changes imply that in our Bi doped $La_{0.67}Sr_{0.33}MnO_3$, the increase of <Mn-O> bond length and decrease of <Bi-O> bond length and <Mn-O-Mn> bond angle are elucidated. The metal-insulator transition and paramagnetic to ferromagnetic transition temperatures are found to decrease with increase of Bi doping till x≤0.3. The samples of x ≥ 0.4 show the insulating charge ordered nature. Markedly, the field dependant magnetization studies of $La_{0.67-x}Bi_xSr_{0.33}MnO_3$ (x=0.3) show the metamagnetic nature of ferromagnetic metallic state implying the competition of coexisting ferromagnetic metallic and charge ordered antiferromagnetic insulating phases. The magnetization studies of $La_{0.67-x}Bi_xSr_{0.33}MnO_3$ (x>0) show the stepwise behaviour which is attributed to the phase separation of ferromagnetic metallic and charge ordered antiferromagnetic insulator phases. The higher doping, $La_{0.67-x}Bi_xSr_{0.33}MnO_3$ (x=0.4 and 0.5) samples show the dominant charge ordered antiferromagnetic phase coexisting with ferromagnetic clusters. The electron spin resonance (ESR) and exchange bias studies also substantiate the coexistence of ferromagnetic clusters in antiferromagnetic matrix. Remarkably, the ESR study along with electrical transport and magnetic studies help to ascertain the coexisting phases in the polycrystalline Bi doped $La_{0.67}Sr_{0.33}MnO_3$ samples.

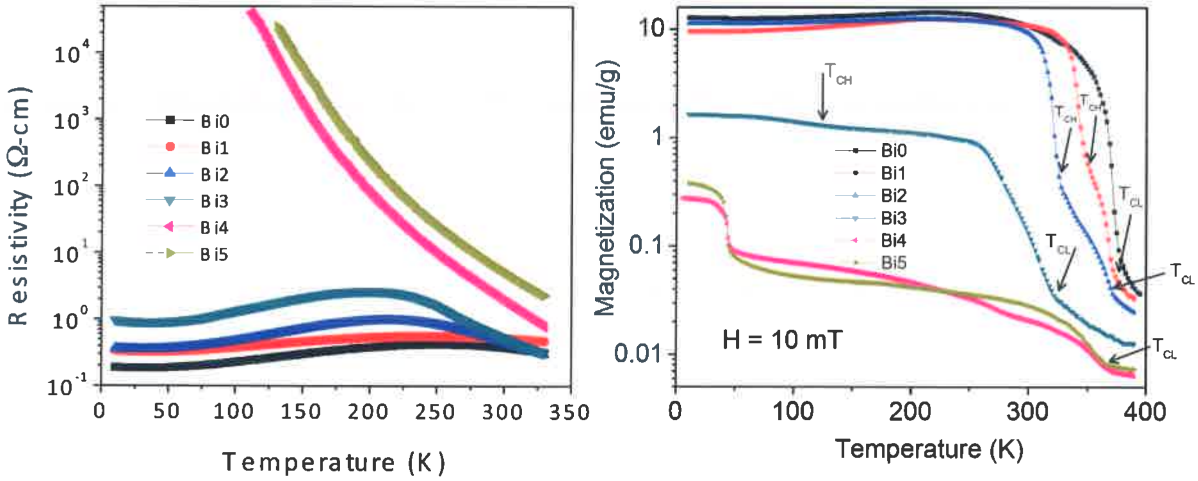


Fig. 3 Temperature dependence of the resistivity and field cooling magnetization of polycrystalline Bi doped $La_{0.67-x}Sr_{0.33}MnO_3$ *(x=0, 0.1, 0.2, 0.3, 0.4 and 0.5), i.e., Bi0, Bi1, Bi2, Bi3, Bi4 and Bi5.*

This work was carried out in collaboration with: Miaoxiang Chen, Peng Li, Xi-xiang Zhang, King Abdullah University of Science and Technology, Kingdom of Saudi Arabia, Desapogu Rajesh, University of Hyderabad, Hyderabad, K. S. Bhagyashree, Lora Rita Goveas, S. V. Bhat, , Indian Institute of Science, P. Anil Kumar and Roland Mathieu, Uppsala University.

A manuscript on this work is submitted to J. Phys. Condens. Matter.

Investigators: Nagaiah Kambhala and S. Angappane

4.14 ANOMALOUS MAGNETORESISTANCE OF BI DOPED $La_{0.67}Sr_{0.33}MnO_3$

We study the magnetoresistance of $La_{0.67-x}Bi_xSr_{0.33}MnO_3$ (x=0, 0.1, 0.2, 0.3, 0.4, 0.5). All the samples show the large magnetoresistance (MR) at low temperatures, which decreases with increasing temperature. We have observed an anomalous large magnetoresistance of up to 100 % for $La_{0.27}Bi_{0.4}Sr_{0.33}MnO_3$ at ~ 90 K. In $La_{0.27}Bi_{0.4}Sr_{0.33}MnO_3$, a field induced insulator to metal transition is observed for 5 and 10 T. Notably, the higher magnetoresistance is observed in samples of competing AFM and FM phases. Nevertheless, the field dependence of low temperature minima indicates the interesting exchange interaction between itinerant conduction electrons and localized spin impurities.

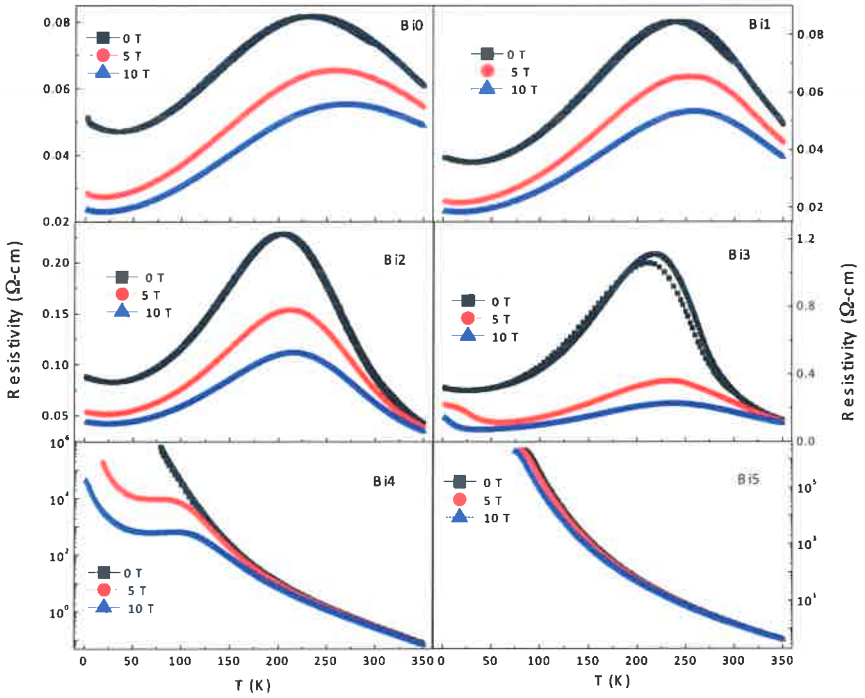


Fig. 4. Temperature dependence of the resistance with different applied magnetic fields, H= 0, 5 and 10 T of $La_{0.67-x}Bi_xSr_{0.33}MnO_3$ *(x=0, 0.1, 0.2, 0.3, 0.4, 0.5).*

This work was carried out in collaboration with: R. Venkatesh, V. Ganesan, UGC-DAE Consortium for Scientific Research, Indore.

A manuscript on this work is under preparation.

Investigators: Nagaiah Kambhala and S. Angappane

4.15 APPLICATIONS OF REDUCED GRAPHENE OXIDE-SILVER NANOPARTICLE HYBRID FILMS AS FLUORESCENT QUENCHING, SURFACE ENHANCED RAMAN SCATTERING SUBSTRATES

Metal nanoparticles when employed as SERS substrates prone to aggregate due to aging and fluoresce strongly upon laser irradiation. Furthermore, in the case of a fluorescent dye as analyte, fluorescence from the molecule also masks the Raman bands. In this work, we have exploited rGO-Ag nanoparticles (rGO-Ag NPs) hybrid ultra-thin films prepared by the inexpensive liquid-liquid interface method, as high sensitive SERS substrates to detect nanomolar concentration of the analyte. Rhodamine 6G (R6G), a highly fluorescent molecule is used as the analyte.

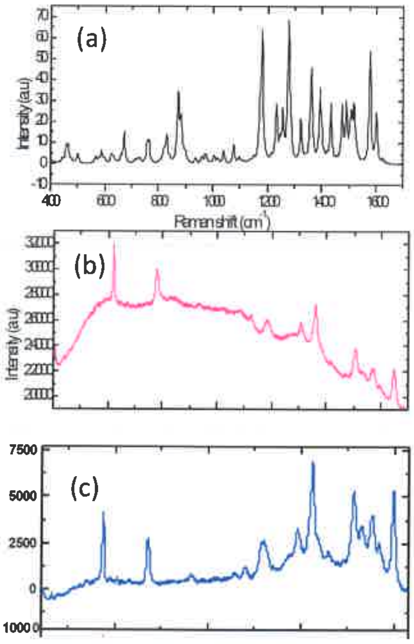


Fig. 1. (a) Calculated Raman spectra of neat R6G (b) Experimental Raman spectra of 1 mM R6G adsorbed on Ag NPs substrate, (c) Experimental Raman spectra of 1mM R6G adsorbed on rGO-Ag NPs hybrid films.

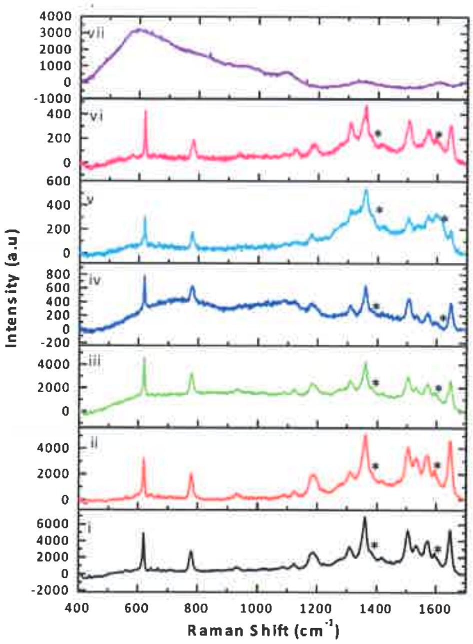


Fig. 2. SERS spectra of R6G adsorbed on rGO-Ag hybrid thin films at different concentrations i) 10^{-3}, ii) 10^{-4}, iii) 10^{-5}, iv) 10^{-6}, v) 10^{-7}, vi) 10^{-8}, vii) 10^{-9} M aqueous solution under 532 nm laser excitation with 1 s accumulation time. Asterisks denote the D and G bands of rGO.

A comparison of the calculated Raman spectra of bulk R6G and Raman spectra of 1mM R6G adsorbed on bare Ag NPs substrate and rGO-Ag NPs substrate is presented in Fig.1. In the case of bare Ag NPs, Raman bands of R6G are seen on a broad fluorescent background (Fig.1b) while on rGO-Ag NPs hybrid thin films, Raman bands are seen strongly enhanced on a flat background (Fig.1c). Raman peaks are seen well resolved in the latter case. Figure 2a shows the SERS spectra of different concentrations ranging from 1mM down to 1nM. It is evident that rGO-Ag NPs hybrid thin films prepared by liquid/liquid interface method could be excellent substrates to detect dye molecule as low as 10^{-8} M concentration.

For the quantitative analysis of the enhanced Raman signal, enhancement (G) factor is calculated from the following equation

$$EF = (I_{SERS} / I_{bulk}) (N_{bulk} / N_{SERS}) \text{ -------- } 1$$

where I_{SERS} is the measured SERS intensity for the probe molecules on the nanoparticle surface, I_{bulk} is the measured intensity of normal Raman scattering from the bulk sample, N_{bulk} is the number of probe molecules under laser illumination in the bulk sample, and N_{SERS} is the number of the molecules probed on the nanoparticle surface. Here, the enhancement factor is calculated for the prominent band at 618 cm^{-1} obtained from 1 mM R6G Raman spectra with 532 nm laser excitation. The enhancement G factor is estimated as 2.3×10^{8} for rGO-Ag NPs substrate, which is very high, obtained for a fluorescent dye.

Generally, the enhancement mechanism arises from 1) Electromagnetic enhancement (EM), 2) charge transfer enhancement (CT). In the case of graphene, enhancement is mainly due to CT. The sp^2-carbon domains in rGO as well as the oxygen-contained groups on the rGO surface, which can be considered possessing a local dipole moment due to the highly electronegative potential of oxygen atom, could contribute an extra local electric field under laser excitation. This mechanism contributes to an enhancement factor of 10^1 to 10^2 in magnitude. For Ag NPs, the enhancement due to EM arising from localized surface plasmons is $10^7 - 10^8$ in magnitude. In the case of rGO-Ag NPs hybrids, a synergic effect due to EM and CT is seen. Ag surface plasmon enhanced Raman signal is further enhanced due to rGO charge transfer effect and fluorescent quenching. This leads to a stronger Raman signal intensity of R6G molecules on rGO-Ag NPs hybrid films than on Ag NPs films alone.

In conclusion, we have demonstrated high SERS performances of rGO-Ag thin film with a fluorescent analyte R6G dye. The estimated enhancement factor 2.3×10^8 is due to the synergic effect from rGO, Ag nanoparticles and rGO-Ag NP interactions. rGO-Ag interactions and R6G-rGO interactions helps in reducing the fluorescence effect from Ag and R6G upon laser illumination.

This work was carried out in collaboration with Dr. C. Kavitha, BMS Institute of Technology, Yelahanka (from outside CNSMS)

This work has been accepted in Chem. Phys. Lett. (2015). Low Cost, Ultra-Thin Films Of Reduced Graphene Oxide-Ag Nanoparticle Hybrids As SERS Based Excellent Dye Sensors, C. Kavitha, K. Bramhaiah, Neena S. John, B.E. Ramachandran, *Chem.Phys.Lett.* 2015 (*in press*)

Investigators : Dr. Neena S. John, Bramhaiah Kommula (within CNSMS including students)

4.16 MORPHOLOGY, PHOTOLUMINESCENCE AND PHOTOCATALYTIC PROPERTIES OF REDUCED GRAPHENE OXIDE-ZNO NANOPARTICLE AND REDUCED GRAPHENE OXIDE-AU-ZNO NANOPARTICLE HYBRID MATERIALS.

ZnO is a II-VI semiconductor with a wide band gap and large excitation binding energy at room temperature and hence its nanomaterials have been explored as potential UV sensors, photocatalysts and photodetectors. Heterogeneous catalysts based on ZnO are found to be efficient for the photodegradation of dye pollutants. The recombination rate of electron-hole pairs resulting in UV band edge emission affects the degradation rate, a faster recombination deterring the degradation efficiency. In this study, we have chosen rGO-ZnO system under different synthesis conditions such as solution phase and hydrothermal route, to probe the effect of morphology and defect states of the ZnO nanostructures when combined with rGO layers or rGO-Au nanoparticles on the photodegradation rates of rhodamine B dye molecules. rGO-ZnO and rGO-Au-ZnO are synthesized by the hydrolysis of zinc acetylacetonate in the presence of rGO or rGO preloaded with gold nanoparticles under hydrothermal conditions and solution based deposition. The morphology studies by SEM shows rod shaped ZnO nanocrystals embedded in rGO layers in the case of rGO-ZnO prepared by hydrothermal conditions (Fig.1a) and aggregated ZnO nanoparticles in the case of rGO-ZnO prepared by solution method (Fig.1b). In the case of rGO-Au-ZnO, hybrid particles consisting of Au and ZnO are observed on rGO layers (Fig.1c).

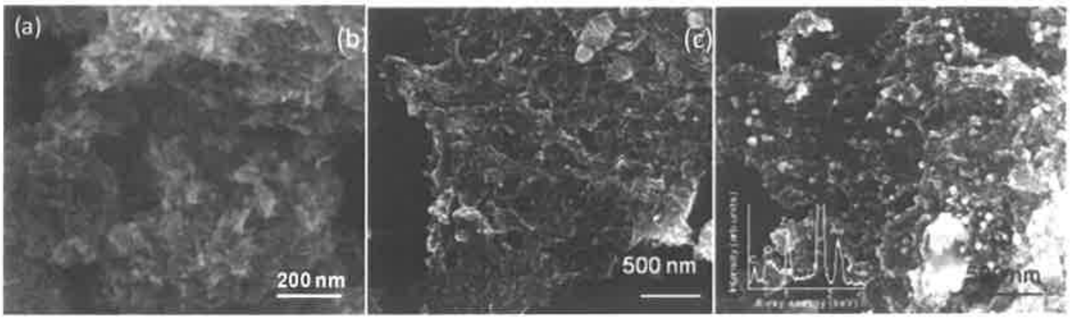


Figure 1. FESEM images of (a) rGO-ZnO nanorods (NRs) by hydrothermal route (b) rGO-ZnO nanoparticles (NPs) by solution deposition (c) rGO-Au-ZnO nanoparticles by solution deposition; bottom inset gives EDS spectra and indicates presence of Au along with ZnO.

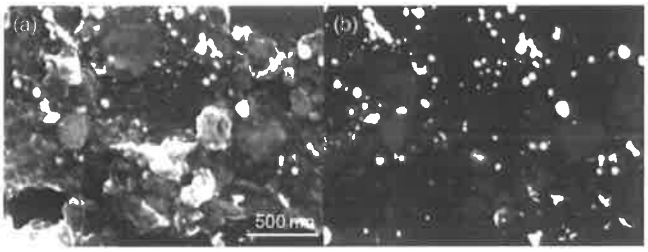


Figure 2. FESEM images of rGO-Au-ZnO NPs a) secondary electron image of a region of the hybrid material b) backscattered image of the same region.

In order to show the distribution and interfacing of Au nanoparticles with ZnO and rGO in rGO-Au-ZnO hybrid system, we have performed back scattered secondary electron imaging. The nanoparticles of Au having highest backscattering coefficient, appear as the brightest spheres in the backscattered image and ZnO nanostructures on rGO appears less bright (Fig.2b).

The photoluminescence (PL) exhibited by these composites give insights into the possible defect states of the nanostructures and may be related to the observed kinetics (Figure 3). The PL spectra of the composites show suppression in the band edge exciton emission at 380 nm when compared to bare ZnO nanoparticles indicating suppression in recombination of electrons and holes due to charge transfer between ZnO and rGO energy levels. The excitonic emission suppression is pronounced in the case of rGO-ZnO NPs and rGO-Au-ZnO NPs and correspondingly we see a higher kinetic rate in these cases than rGO-ZnO NRs (Fig.3c). For rGO-ZnO NPs, the defect emissions of ZnO in the visible region are also suppressed indicating charge transfer across defect levels and rGO. In the case of rGO-Au-

ZnO NPs, Au NPs offer an alternate route for charge transfer along with rGO and hence they offer the highest degradation rate among the various hybrid materials studied here (Fig. 3b and 3c).

In conclusion, we have studied the role of charge transfer states and defect levels in the photdegradation rates of ZnO based catalysts by coupling with rGO and rGO-Au NPs prepared by different synthetic routes. The photodegradation rates are in the order rGO-Au-ZnO nanoparticle > rGO-ZnO nanoparticle > rGO-ZnO nanorods > bare ZnO nanoparticle. The observed difference in kinetics can be correlated with photoluminescence. A suppression of UV band edge emission with the introduction of rGO and Au indicates facilitation of charge transfer to intermediary energy levels increasing the lifetime of holes and electrons. Defect emissions are also seen that vary with different morphologies. Furthermore, the effective dye concentration in the presence of rGO-ZnO composites is found to be much lesser than bare ZnO. Hence, rGO acts as an efficient adsorbent and charge transfer agent assisting the photodegradation performance of ZnO.

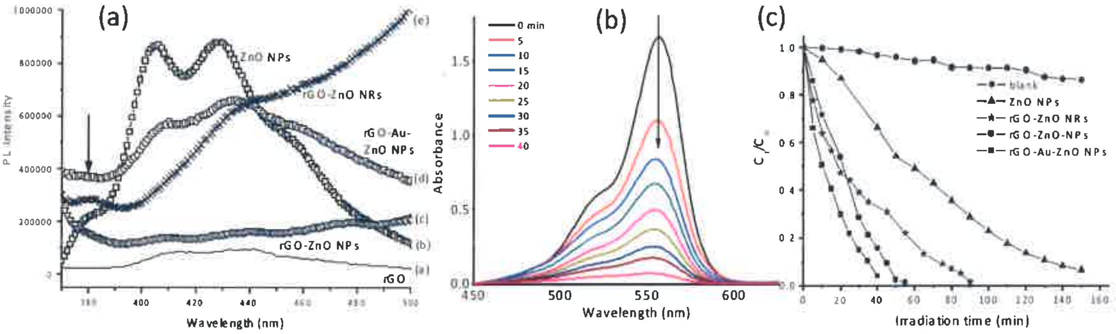


Fig.3 (a) PL spectra (λ_{ex} – 325 nm) of ZnO, rGO-ZnO and rGO-Au-ZnO NPs nanocomposites prepared by solution phase method and hydrothermal method. (b) Time evolution UV-Vis spectra of 40 µm RB dye solution in presence of rGO-Au-ZnO NPs catalyst when irradiated with 365 nm light intensity of 110 mW/cm^2. (c) Kinetics of 40 µm RB dye degradation in the absence and presence of various catalysts (10 mg), bare ZnO NPs, rGO-ZnO NPs, rGO- ZnO NRs and rGO-Au-ZnO-NPs.

Investigators : Dr. Neena S. John, Bramhaiah Kommula (within CNSMS including students)

4.17 ELECTRICAL RESPONSIVE STUDIES OF METAL PHTHALOCYANINES TO HUMIDITY USING CONDUCTING ATOMIC FORCE MICROSCOPY

Metal phthalocyanines are p-type semiconductors with conjugated π–electron systems, having 18 π-electrons in their skeletal structure. The delocalization of these π-electrons over the entire system acts like charge carriers to make them conductive. As a result of their good electrical response, metal phthalocyanines are used as sensitive materials in the field of fabricating sensors.

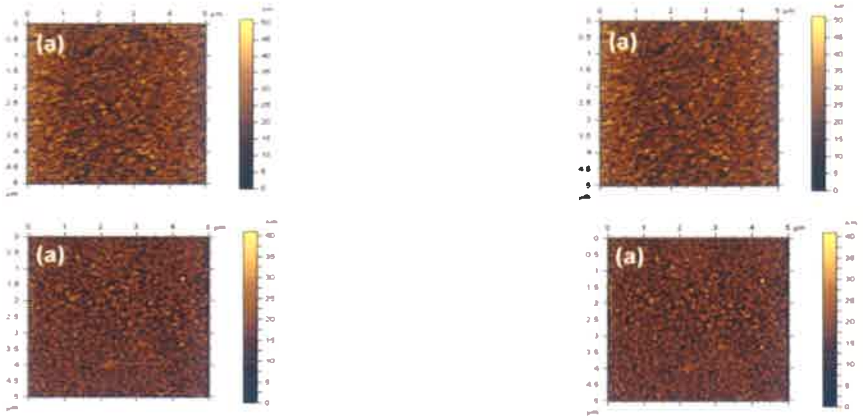


Figure 1. AFM images of metal phthaocyanines thin film at different RH conditions, top Panel: CuPc and bottom panel: PbPc. (a) morphology (b), (c) and (d) are the current images at 65% RH, 85% RH and 10% RH respectively

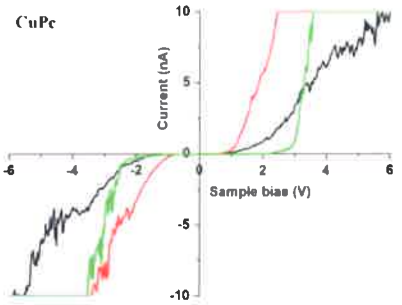


Figure 2. I-V characteristics of CuPc showing change in band gaps upon film exposure to different RH

10%

In this study, the electrical sensitivity of copper phthalocyanine (CuPc) and lead phthalocyanine (PbPc) thin films are probed at molecular level using C-AFM under relative changes in humidity (RH), 10%, 65% and 85%. The changes in conductivity of the metal phthalocyanine films may be attributed to the adsorption of water molecules on the surface. On applying bias using conductive AFM tip, in situ electrolysis of water molecules occur which liberates oxygen species. These oxygen molecules coordinate to the central metal atom and influence the electronic structure of metal phthalocyanine. This metal phthalocyanine - O_2 interaction leads to shifting of molecular orbitals in energy scale. The resulting HOMO – LUMO gap is narrower than conventional metal phthalocyanine and hence increase in conductivity is observed. The current images (Figure 1) reveal that the electrical response so obtained is not a grain boundary effect but a uniform bulk effect all over the surface. At low humidity level, where N_2 is used as a carrier gas, will cause oxygen to desorb from the film gradually thereby, decreasing the current (Figure 1d). At 85% RH, slight decrease in current could be due to the multilayer adsorption of water molecules onto the sample surface (Figure 1c). In-situ O_2 generated species are retained over the surface, than effectively transported through the bulk. It is found that 65% RH is the optimum RH showing high current sensitivity of the films (Figure 1b), while at 85% RH, the sensitivity of the films begin to degrade. Further, the I-V curves obtained in different conditions reveal that the adsorbed analyte affects the HOMO – LUMO alignment and thereby change in band gap (Figure 2).

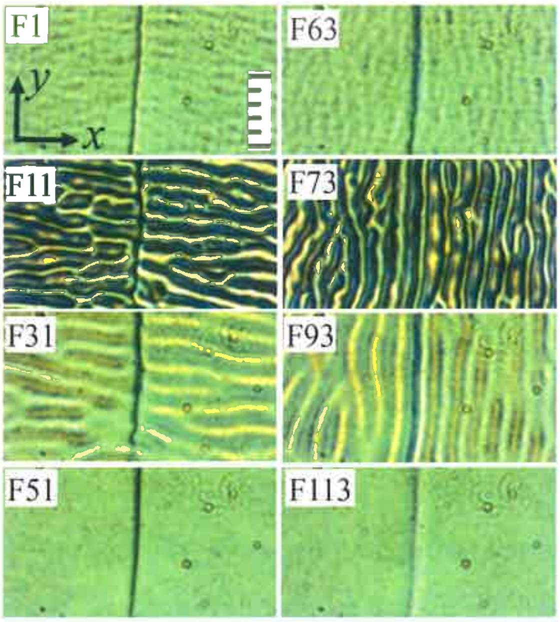
In conclusion, we have been able to study the local conductance map of metal phthalocyanines under different humidity conditions using conducting atomic force microscopy. The conduction channels are observed throughout the grains rather than through boundaries and number of grain contribution to the overall current increase with increase in humidity.

This work was done under the DST fast track project.

Investigators : Dr. Neena S. John, Priya Madhuri K. (within CNSMS including students)

4.18 SPATIOTEMPORAL CHARACTER OF THE BOBYLEV-PIKIN FLEXOELECTRIC INSTABILITY IN A TWISTED NEMATIC BENT-CORE LIQUID CRYSTAL EXPOSED TO VERY LOW FREQUENCY FIELDS

The Bobylev-Pikin striped-pattern state induced by a homogeneous electric field is a volume flexoelectric instability, originating in the midregion of a planarly aligned nematic liquid crystal layer. The present work reveals that the instability acquires a spatiotemporal character upon excitation by a low frequency (<0.5 Hz) square wave field. This is demonstrated using a bent-core liquid crystal, initially in the 90°-twisted planar configuration. The flexoelectric modulation appears close to the cathode at each polarity reversal and, at low voltage amplitudes, decays completely as the field becomes steady. Correspondingly, at successive polarity changes, the stripe-direction switches between the alignment directions at the two substrates (Fig. 1, 2). For large voltages, the stripes formed nearly along the alignment direction at the cathode gradually reorient toward the midplane director. These observations are generally attributed to inhomogeneous and time-dependent field conditions that come to exist after each polarity reversal. Polarity dependence of the instability is attributed to the formation of intrinsic



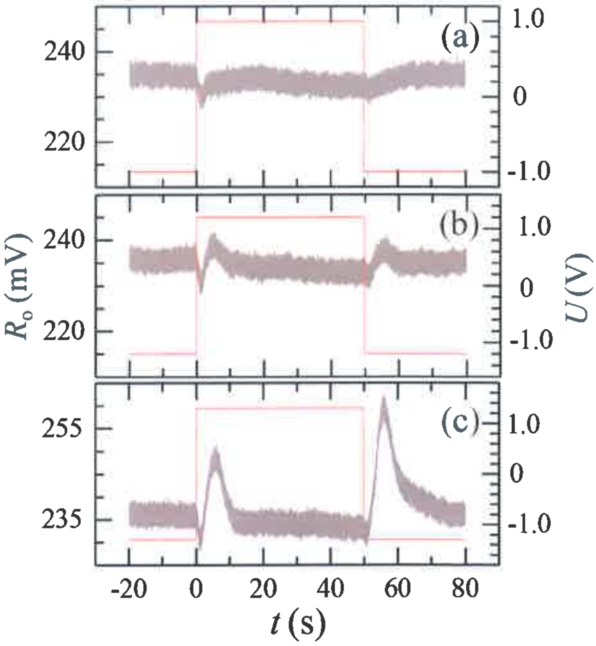


Fig. 1 (Left) Transient evolution of horizontal and vertical stripe-states occurring at successive polarity reversals of a square wave field (f=0.0263 Hz, U=2.5 V) in a 90^o-twisted nematic sample of 11Cl at 90^o C. Here FX refers to the Xth frame of the time-lapse series, with a frame rate $f_R = 124 f = 3.257\ s^{-1}$. Frames recorded at successive polarity reversals F1 and F63 are separated by 61 frames (F2-F62) captured during imposed field constancy. 4 μm each scale div.

Fig. 2 (Right) Transient director field modulation following field polarity switch at low bias voltages as revealed by time variation of optical response R_o (gray line) in a layer of twisted nematic 11Cl exposed to a 10-mHz square wave field (red line). Applied voltage is (a) 1.0 V, (b) 1.2 V and (c) 1.3 V.

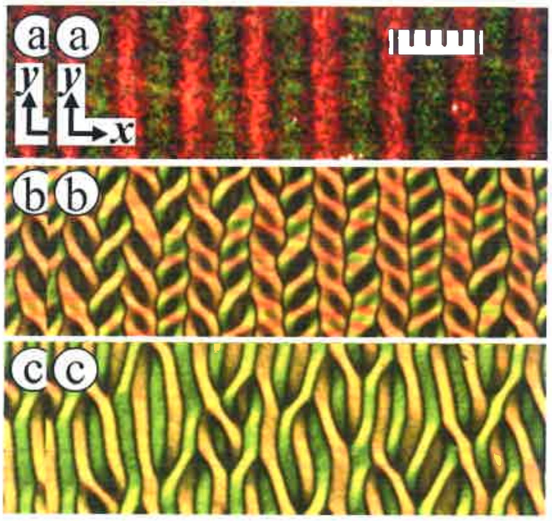
double layers that bring about an asymmetry in surface fields. Momentary field elevation near the cathode following a voltage sign reversal and concomitant gradient flexoelectric polarization are considered the key factors in accounting for the surface-like modulation observed at low voltages.

This work has been published: K. S. Krishnamurthy, Phys. Rev. E **89**, 052508 (2014)

Investigators : K. S. Krishnamurthy

4.19 DISLOCATIONS AND METASTABLE CHEVRONS IN THE ELECTROCONVECTIVE INPLANE NORMAL ROLL STATE OF A BENT CORE NEMATIC LIQUID CRYSTAL

This work relates to experimental results on the formation, dynamics and annihilation of edge dislocations of opposite topological charge in the electroconvective inplane vortex state of a bent-core nematic liquid crystal. The approach of paired oppositely charged defects toward each other is a two step process. Near constant velocity at large separation and accelerated motion close to annihilation are found, as in the case of nematic rolls belonging to standard electroconvection. Periodic arrays of dislocations of alternating polarity form upon a sudden, strong elevation of the control parameter (Fig. 1). Chevron structures that appear between undulatory defect chains are metastable and their decay with time is accompanied by an exponential reduction in the dislocation density (Fig. 2). The initial periodicity of defect chains also drops exponentially with increasing field.



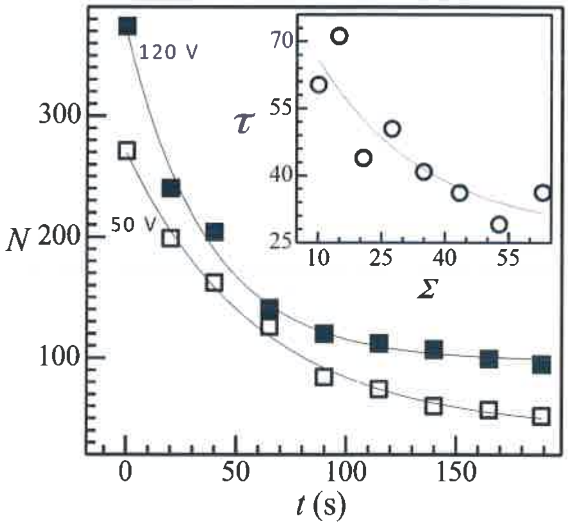


Fig. 1. (Left) Formation and relaxation of metastable chevrons in supercooled nematic 9CN. (a) Inplane normal roll state near the threshold; (b) Chevrons formed a few seconds after suddenly increasing the voltage. (c) The usual edge dislocation state to which the chevron state in panel (b) has relaxed after 200 s. 10 μm each scale div.

Fig. 2. (Right) The number of edge dislocations N in a 320x210 μm^2 area of the sample as a function of time. The time t=0 corresponds to that of fully developed chevron state obtained after a few seconds of switching the voltage. Inset: Relaxation time as a function of control parameter; the continuous line indicates τ(ε) to be broadly an exponentially decreasing function.

This work has been published: K. S. Krishnamurthy, Pramod Tadapatri and P. Viswanath, *Soft Matter*, **10**, 7316 (2014)

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

4.20 ELECTRICAL CONDUCTIVITY IN THE LANGMUIR-BLODGETT FILMS OF n-ALKYL CYANOBIPHENYLS USING CURRENT SENSING ATOMIC FORCE MICROSCOPE

We have carried out studies on the nanoscale electrical conductivity in monolayers of n-alkyl cyanobiphenyl (nCB) materials deposited on solid surface. The 8CB, 9CB and 10CB monolayer films were prepared by Langmuir technique at air-water interface and characterized by surface manometry and Brewster angle microscopy. The monolayer films were transferred on to solid substrates by Langmuir-Blodgett (L-B) technique. The 8CB, 9CB and 10CB monolayer L-B films transferred onto freshly cleaved mica were studied by atomic force microscope (AFM). The AFM topography yields a thickness of the film to be ~1.5 nm. The electrical conductivity measurements were carried out on 9CB and 10CB monolayer L-B films transferred onto highly ordered pyrolytic graphite (HOPG) employing a current sensing AFM. In the set up, the conducting tip - monolayer- conducting substrate form a system of metal-insulator-metal (M-I-M) junction.

The CS-AFM conductivity image for 9CB monolayer deposited on HOPG along with the current profile is shown in figure 1. The nanoscale current-voltage (I-V) measurements show a non-linear variation. Typical I-V characteristics for 9CB deposited on HOPG is shown in figure 2(a). The nature of the curve indicates electron tunnelling to be the mechanism for electrical conduction. To analyse our results, we have used Simmons generalized equation for tunnelling current in a system of (M-I-M) junction. The analysis of the I-V curve based on Simmons approach reveals a transition in the electron conduction mechanism from direct tunnelling to injection tunnelling. For 9CB, the plot indicating the transition is shown in figure 2(b). Similar measurements and analysis were carried for the material 10CB. From the transition voltage, we have estimated the barrier height for 9CB and 10CB to be 0.71 eV and 0.37 eV respectively. For 9CB and 10CB, the effective mass of electron were calculated and they turn out to be $0.021m_e$ and $0.065m_e$ respectively. These parameters are important in designing molecular electronic devices.

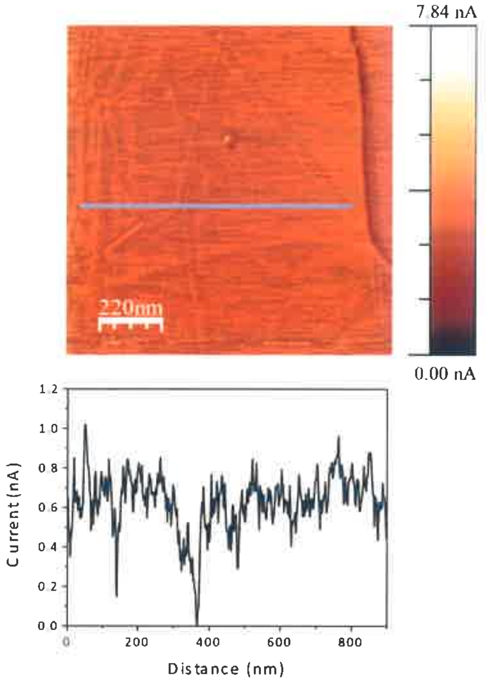


Figure 1. CS-AFM conductivity image for 9CB monolayer deposited on HOPG. The current profile drawn across the image yields a current of about 700 pA. The dark line seen on the right side in the image is a step in the HOPG substrate.

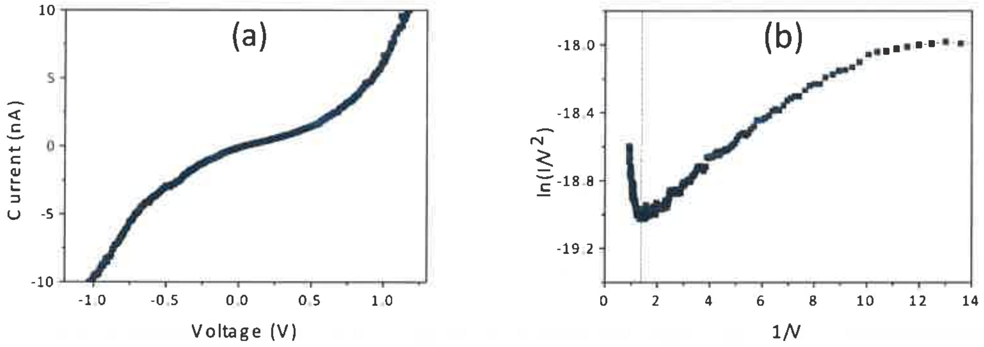


Figure 2. (a) Typical current -voltage (I-V) characteristics for 9CB deposited on HOPG. (b) Plot of ln(I/V^2) Vs (1/V) for 9CB indicates a transition from direct tunnelling to injection tunnelling. The dashed line indicates the transition voltage (V_{trans}).

Investigators: K. A. Suresh and H. N. Gayathri

5. SPONSORED PROJECTS

- A three year project entitled "Optically active supramolecular liquid crystals, photochromic trimers and functional trimer-lke mesogens: Synthesis and characterization" under the DST Women Scientist Scheme A (WOS-A) was sanctioned in January 2014. The project is under progress. [Investigator: Uma S. Hiremath and Project Mentor: Geetha G. Nair].

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

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

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

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

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

- An Indo-Bulgarian research project proposal entitled "Investigation of photostimulation effects in nano-structured liquid crystals" was sanctioned by DST in February 2013. The first instalment of grant has been received. The project is under progress. [Investigators: Indian side - S.Krishna Prasad, Geetha G.Nair, D.S. Shankar Rao and C. V. Yelamaggad; Bulgarian side – Y. G. Marinov, A. G. Petrov, G. B. Hadjichristov, L. Todorova and M. Dencheva-Zarkova]

  As a part of the project, Dr. Yordan G. Marinov, Assistant Professor, Institute of Solid State Physics, Bulgarian Academy of Sciences, Sofia will be visiting the Centre for 20 days from 21 October 2014 to 9 November 2014.

- Under the ongoing INSA-Hungarian Exchange Programme, during the year 2014, Profs.Agnes Buka and Tamas Borzsonyi, Researchers, Institute for Solid State Physics and

Optics, Wigner Research Centre for Physics, Hungary visited the Centre for 13 and 14 days respectively during 04-18 November 2014.

Under the above mentioned Programme, Dr. Geetha G. Nair visited Department of Complex Fluids, Institute for Solid State Physics and Optics Wigner Research Centre for Physics of the Hungarian Academy of Sciences Budapest, during 20 September 2014 to 06 October 2014 (Two weeks).

6. WOMEN'S DAY

The International Women's Day was celebrated on 10 March 2015. On this occasion, the women staff members of the Centre had a meeting at the Centre to discuss matters of common interest and planted seedlings.

7. NATIONAL SCIENCE DAY

The Centre celebrated the National Science Day on 27 February 2015, declaring it the Open Day for the public. The occasion was celebrated by organizing a series of lectures by the CNSMS scientists for an invited audience consisting of about 45 students and a few teachers of the MES Kishore Kendra Public School, Vidyaranyapura, Bengaluru. The talks were on :

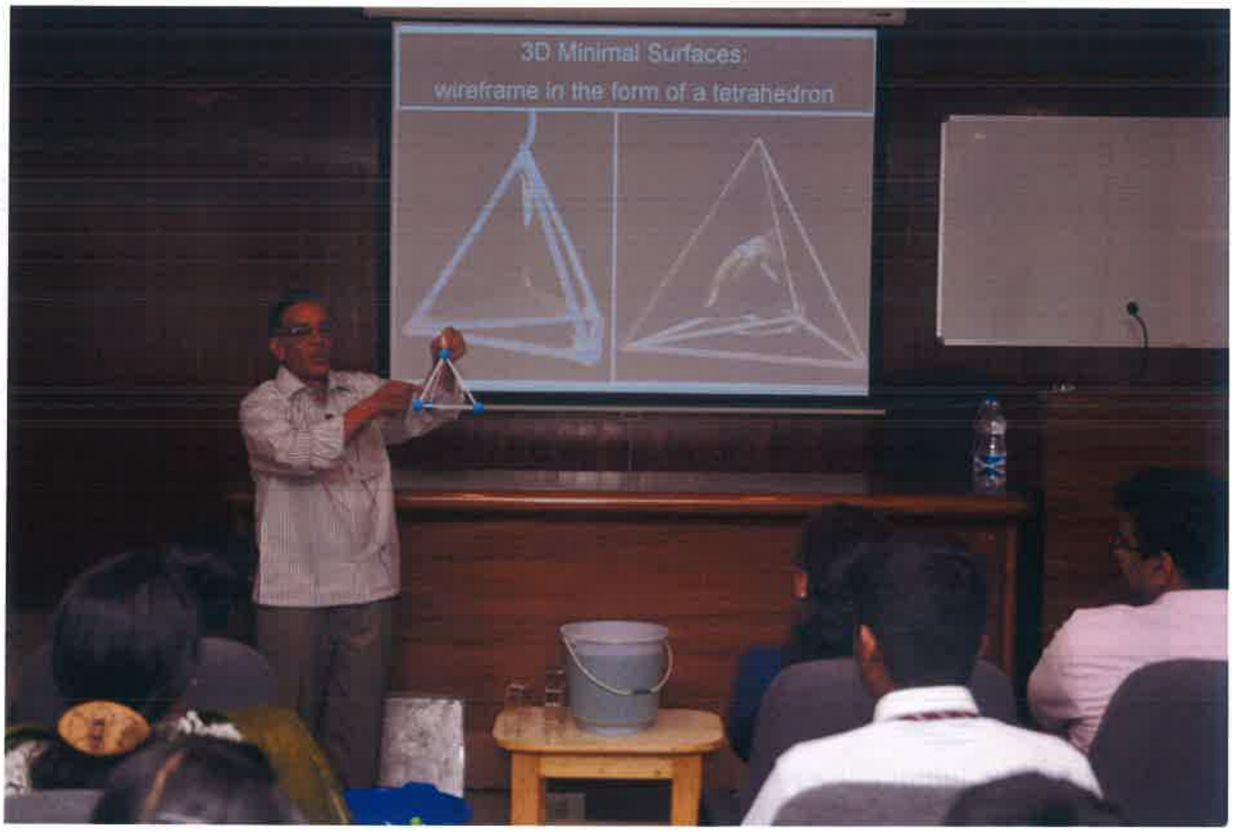
Title	Speaker
Science Day and Raman effect	Prof. K. A. Suresh
Small cause, large effects	Dr. Geetha G. Nair
Some surprises with liquid drops	Dr. P. Viswanath
Minimal surfaces	Prof. K.S. Krishnamurthy
Mimicking nature	Dr. S. Krishna Prasad
Discovery of nuclear fission	Prof. H.L. Bhat
Puzzling optical phenomena	Prof. G.S. Ranganath

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

Students at the National Science Day Lecture.

Students from MES Kishore Kendra Public School in rapt attention during a lecture.

Dr. Gettha G. Nair delivering a lecture.



Prof. K. S. Krishnamurthy demonstrating an experiment.

Students having a first hand experience.

Dr. S. Krishna Prasad delivering a lecture.

Students participating in a demo in a lab.

Our research scholars explaining about an experiment.

Students in the Chemistry Lab.

8. PROF. S. CHANDRASEKHAR MEMORIAL LECTURE

The 11th Prof. S. Chandrasekhar Memorial Lecture was delivered by Prof. D.D.Sarma, Solid State and Structural Chemistry Unit, Indian Institute of Science, Bengaluru on 6 August 2014. The lecture was on “Never ending surprises: Photoluminescence in nanocrystals”.

Prof. D. D. Sarma being given a warm welcome.

Prof. K. A. Suresh giving the introductory speech.

Prof. N. Kumar addressing the gathering.

Prof. D. D. Sarma delivering the Lecture on 'Photoluminescence in nano crystals'.

Audience at the Memorial Lecture.

9. STUDENTS' PROGRAMME

- M. Vijay Kumar attended 25th International Liquid Crystal Conference-2014 held at Dublin, Ireland during 29 June – 4 July, 2014 and made an oral presentation entitled "Enhancement of electrical conductivity, dielectric anisotropy and director relaxation frequency in composites of gold nano -particle and a weakly polar nematic liquid crystal".

- M. Vijay Kumar attended 25th International Liquid Crystal Conference-2014 held at Dublin, Ireland during 29 June – 4 July, 2014 and made a poster presentation entitled "Novel columnar–calamitic phase sequences in a binary system of bent-core and rod-like mesogens".

- M. Vijay Kumar attended 21st National Conference on Liquid Crystals-2014 held at Kanpur during Nov 10-12, 2014 and made an oral presentation entitled "Enhancement of electrical conductivity, dielectric anisotropy and director relaxation frequency in composites of gold nano -particle and a weakly polar nematic liquid crystal".

- P. Lakshmi Madhuri attended the 2nd Asian Conference on Liquid Crystals (ACLC-2015) held at Busan, Korea during 19-21 Jan 2015 and made an oral presentation entitled “Effect of Photo-isomerization on the Frank elastic constants of the banana shaped molecules and its application as dual-frequency optical switch”

- Vimala S. attended the 59th DAE - Solid State Physics Symposium held at VIT University, Vellore, Tamilnadu, during 16-20 December, 2014 and presented a poster titled “Influence of polarization-tilt coupling on the ferroelectric properties of smectic gels”.
- Bhargavi R. gave Ph.D. defense talk titled “Rheological studies of liquid crystal gels and composites” at Physics department, Mangalore University, Mangalore, 9th March 2015.
- Rashmi Prabhu submitted her thesis to the Mangalore University on 20th July 2014. Following this, she appeared for her viva-voce examination on 13th January 2015 and succeeded. Based on the favorable reports of the two examiners and her excellent performance in the viva-voce examination, the board of examiners recommended the award of Ph.D. degree (Chemistry) to her.
- N.G. Nagaveni submitted her Ph.D. thesis titled “Novel photochromic liquid crystals: Synthesis and mesomorphic properties, in June 2014 to Mangalore University.
- Chandan Kumar attended the workshop on Micro and Nano fabrication – 2015 held at IIT Kanpur during 16-20, March 2015.
- R. Rajalakshmi attended the 59th DAE Solid State Physics Symposium (DAE-SSPS 2012) held at VIT University, Vellore, Tamilnadu, during December 16-20, 2014 and presented poster entitled “Resistive switching behavior of RF magnetron sputtered ZnO thin films”.
- Nagaiah Kambhala attended the 4th International Conference on Superconductivity and Magnetism (ICSM2014) held at Antalya, Turkey during April 27- May 2, 2014 and presented poster “Out-of-plane electrical properties of $La_{0.67}Ca_{0.33}MnO_3$ thin film”.
- K. Bramhaiah Nano INDIA 2015, SASTRA University, Thanjavur, INDIA, 29 - 30 January 2015 and made a poster presentation titled “Nanocomposites of zinc oxide with reduced graphene oxide and their photocatalytic properties”.

- Arup Sarkar attended International Conference on Soft Materials (ICSM 2014) held during October 6-10, 2014 at Malaviya National Institute of Technology (MNIT), Jaipur and made a poster presentation titled "Thin films of graphene oxide – cholesterol biomolecules at air-water, air-solid interfaces".

10. POPULARIZATION OF SCIENCE

PROF. K. A. SURESH

	Name of the Institute	Date	Title of talk
1.	Mangalore University, Mangalagangotri	05.09.2014	Teachers role in science education
2.	Lucknow University, Lucknow	13.11.2014	Soft matter : Liquid crystals, polymers, gels etc.

DR. KRISHNA PRASAD

	Name of the Institute	Date	Title of talk
1.	Karnataka Rajya Vijnana Parishat, Gulbarga	15.07.2014	Jeevakosha, LCD mattu dravasphatikagala mayaloka

DR. C.V.YELAMAGGAD

	Name of the Institute	Date	Title of talk
1.	M.S. Ramaiah College of Arts, Science and Commerce and presented an invited lecture to popularize basic research and applied science.	06.01.2015	"The existence of an unusual and unique state of matter"
2.	Mangalore University, Mangalore. Presented an invited lecture addressing general M.Sc. students	29.09.2014	"Liquid crystals- An unique state of matter"

PROF. H. L. BHAT

	Name of the Institute	Date	Title of talk
1.	The Bangalore Science Forum, National College, Basavanagudi, Bengaluru	30.04.2014	Can light behave differently under certain circumstances?

2.	First Refresher Course In Materials Preparation And Measurement Of Properties, Fellows Residency, Jalahalli, Bengaluru	12.04.2014	Crystals and their growth
3.	KRVP Programme in Mysuru	03.07.2014	Crystals: Nature's wonder
4.	Second Refresher Course In Materials Preparation And Measurement Of Properties, Fellows Residency, Jalahalli, Bengaluru	19.09.2014	Crystals and their growth
5.	Jain College VV Puram, Bengaluru	17.12.2014	Crystals: Nature's wonder
6.	Third Refresher Course In Materials Preparation And Measurement Of Properties, Fellows Residency, Jalahalli, Bengaluru	15.12.2014	Crystals and their growth
7.	AES National PU College, Gauribidanur on Science Day Celebration	28.02.2015	C.V.Raman and Laser?
8.	Talent Development Centre, Indian Institute of Science, Kudhapura, Challakere Chitradurga District , Karnataka	29-30 June 2014 30 June-1 July2014 7-8 July 2014 11-12 Aug. 2014 1-2 Sept. 2014 30 Oct. 2014 10-11 Nov. 2014	Lectures with the following titles were given on these days: Electromagnetic Radiation, Photoelectric effect, Laser :Light of the 20th Century, Lasers and Applications, Optics through Laser, Atomic Structure and related Developments

11. VISITS ABROAD AND TALKS GIVEN

- Under the framework of Indo-Bulgarian joint project, Dr. S. Krishna Prasad visited Institute of Solid State Physics, Sofia, Bulgaria from 13 – 21 October 2014 and gave a talk on "Liquid Crystal Gels: Rheological, Electrical and structural Properties" on 17th October 2014
- Prof. K. A. Suresh attended 25th International Liquid Crystal Conference held at Trinity College, Dublin, Ireland during 29 June to 4 July 2014 and gave an Invited Talk titled "Fluorescent dye induced spreading and retraction dynamics of liquid crystal domains at air-water interface".
- Prof. K. A. Suresh visited the Dept. of Electronic and Electrical Engineering, University of Dublin during July 5 to July 12, 2014 and gave a colloquium on "Nanoscale electrical conductivity in ultra thin films of liquid crystalline materials" on 9 July 2014.

12. SEMINARS / TALKS GIVEN AT OTHER INSTITUTES

- Dr. S. Krishna Prasad attended Two-day workshop on Xray Crystallography held at MS Ramaiah Institute of Technology, Bengaluru during 30 June-01 July 2014 and gave an Invited Talk titled "Some examples of Xray diffraction studies on non-crystalline materials".
- Dr. S. Krishna Prasad attended the 21st National conference on Liquid Crystals held at VSSD College, CSJM University Campus, Kanpur during 10-12 November 2014 and gave an Invited Talk titled "Photo-stimulated effects in bent-core liquid crystals". Also Chaired a session.
- Dr. Geetha G. Nair attended the 21st National conference on Liquid Crystals held at VSSD College, CSJM University Campus, Kanpur during 10-12 November 2014 and gave a lecture titled "Anchoring transition induced by gelation in a nematic liquid crystal".
- Dr. D.S.Shankar Rao attended the 21st National conference on Liquid Crystals held at VSSD College, CSJM University Campus, Kanpur during 10-12 November 2014 and gave a lecture titled "Viscoelastic behaviour of a binary system of strongly polar bent-core and rod-like nematic liquid crystals". Also chaired a session.
- Prof. K.A. Suresh attended the 21st National conference on Liquid Crystals held at VSSD College, CSJM University Campus, Kanpur during 10-12 November 2014 and gave an Invited Lecture titled "Photo-induced spreading dynamics of 2 dimensional domain in the vicinity of nematic – smectic phase transition". Also chaired a session.
- Prof. K.A. Suresh attended the 9th National Conference of Physics Academy of North East, held at North Eastern Regional Institute of Science and Technology (NERIST), Itanagar, Arunachal Pradesh during 18-20 December, 2014 as Keynote Speaker and gave a Lecture titled "Nanoscale electrical and mechanical properties of thin films of discotic molecules using atomic force microscope".
- Prof. K.A. Suresh attended National Conference on "Recent trends in Physics, Mathematics and Engineering" at Sarada Vilas College, Mysuru during 20-21 February 2015 as Keynote Speaker and gave a Lecture titled "Nanoscale measurements of physical properties in thin films" on 20.02.2015.

- Prof. K.A. Suresh visited Department of Physics, University of Lucknow and gave a Colloquium titled "Properties of thin films of discotic liquid crystals" on 14.11.2014.
- Prof. K.A. Suresh visited Department of Physics, University of Mysore and gave a Colloquium titled "Thin liquid crystal films at intrafaces" on 19.02.2015.
- Dr. Veena Prasad visited Vijaya College Mulki and attended State level Seminar on "Chemistry of Advanced Materials" held on January 5, 2015 and gave an Invited Lecture titled "Liquid Crystals".
- Dr. C.V.Yelamaggad participated in two day National Conference on "Advanced Nanotechnology and its Applications" held at Maharani's science college for women, Bengaluru during 22-23 January 2015 and gave an invited lecture titled "Liquid crystals and nano world: Science and technology without boundaries".
- Dr. C.V.Yelamaggad participated in two day National Conference on "Present Scenario of Chemical Sciences and its Technological Perspectives" held at Department of Karnataka Science College, Dharwad during 10-11 October 2014 and gave an invited lecture titled "Liquid crystals: Fundamentals; properties and applications".
- Dr. C.V.Yelamaggad visited Department of Chemistry, Mangalore University, Mangalore on 29 September 2014 and presented 6 course lectures titled "Liquid Crystals" to 3rd semester M.Sc. Industrial Chemistry students.
- Dr. C.V.Yelamaggad visited BMS Engineering college, Bengaluru under science-forum on 10 September 2014 and presented an Invited Talk titled "Crystals that flow".
- Dr. P.Viswanath attended the 21st National conference on Liquid Crystals held at VSSD College, CSJM University Campus, Kanpur during 10-12 November 2014 and gave a lecture titled "Dynamics of dislocations and metastable chevrons in a bent core nematic liquid crystal".
- Dr. P. Viswanath attended the short term Workshop on Micro and nano-fabrication – 2015 held at IIT Kanpur during 16 – 20 March 2015 and gave an Invited Lecture entitled "Organic thin films at interfaces".
- Dr. P. Viswanath visited IIT Kanpur on 20 March 2015 and gave a colloquium titled "Dynamics of liquid crystals at interfaces".
- Dr. S. Angappane attended project review cum Group Monitoring Workshop (GMW) on SERB/DST Young Scientists Scheme (YS) in Department of Physics, Indian Institute of

Technology Guwahati during 4 - 5 November, 2014 and gave a talk on "Studies on doped ZnO thin films and resistive switching applications".

- Prof. K.S. Krishnamurthy attended the 21st National conference on Liquid Crystals held at VSSD College, CSJM University Campus, Kanpur during 10-12 November 2014 and gave an Invited Lecture titled "Polarity sensitive transient flexoelectric and electroconvective states in twisted nematic liquid crystals driven by very low frequency fields".
- Prof. H.L.Bhat attended the 26th AGM of Materials Research Society of India held at University of Rajasthan, Jaipur during February 9-11, 2014.
- As an Invited Speaker and Session Chairman, Prof. H.L.Bhat attended the International conference on Crystal Science and Engineering (ICCSE-2014) held at School of Electrical & Electronics Engineering, SASTRA University, Tanjavur during November 28-29, 2014 and gave a talk on "Biaxial Nonlinear Optical Crystals of Ascorbic Acid Family".
- As Invited Speaker, Prof. H.L.Bhat attended International Interdisciplinary conference on the Frontiers of Crystallography (IICFC:2014) held at F M K M Cariappa College, Madikeri during December 29-30, 2014 and gave a talk "Crystal Growth of certain Non-linear Optical (NLO) Materials".
- Prof. H.L.Bhat attended National Seminar on Physics of bulk and nano materials and devices held at Department of Physics, Bharatidasan Institute of Technology, Anna University, Tiruchirapalli-620024 March,19-20, 2014. He gave Inaugural Address and also gave Keynote Lecture titled "Physics of Non-linear Optical (NLO) Crystals and their device applications".

13. LECTURES BY VISITORS

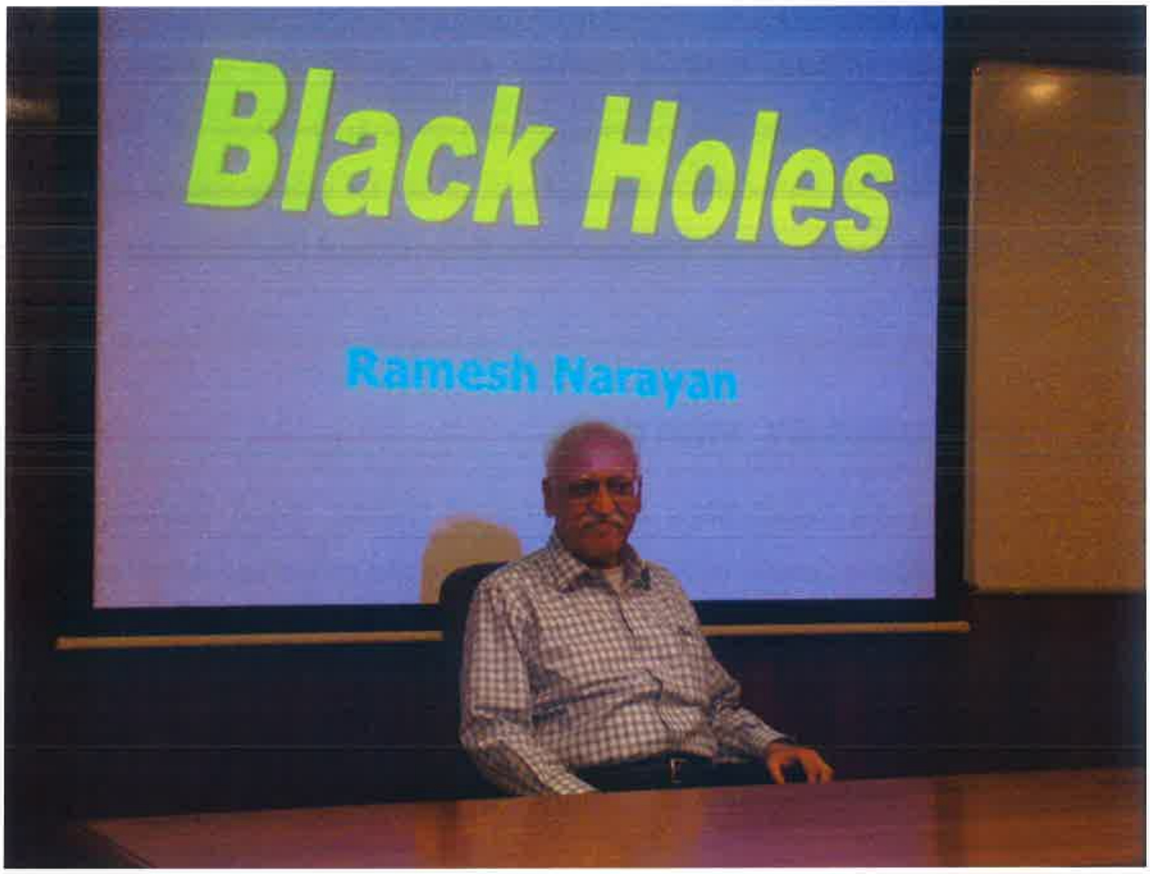
- Prof. S. Anantha Ramakrishna Department of Physics, Indian Institute of Technology, Kanpur visited the Centre on 26 September 2014 and gave a Seminar titled "Plasmonics of periodically patterned columnar thin films".

- As a part of the on-going Indo-Bulgarian Joint Programme Dr. Yordan G. Marinov, Georgi Nadjakov Institute of Solid State Physics, Sofia, Bulgaria visited the Centre during 21 October 2014 to 9 November 2014 and gave a colloquium titled Flexo-dielectro-optical spectroscopy as a method of studying nanostructured nematic liquid crystals on 31 October 2014.

- Under the ongoing INSA-Hungarian Exchange Programme, during the year 2014, Profs. Agnes Buka and Tamas Borzsonyi, Researchers, Institute for Solid State Physics and Optics, Wigner Research Centre for Physics, Hungary visited the Centre for 13 and 14 days respectively during 04-18 November 2014. Dr. Tamas Borzsonyi gave a colloquium titled "How do granular materials flow ?" on 7 November 2014. Further Prof. Agnes Buka also gave a colloquium titled "Equilibrium - nonequilibrium: Introduction to pattern formation" on 7 November 2014.

- Prof. J. K. Vij Trinity College, University of Dublin, Dublin, Ireland visited the Centre on 21 November 2014 and gave a colloquium titled "Flexoelectric driven electroclinic effect in a twist bend nematic phase".

- Prof. Ramesh Narayan, FRS Thomas Dudley Cabot Professor of the Natural Sciences, Harvard University, Cambridge, MA, USA visited the Centre on 12 March 2015 and gave a Public Lecture titled "Black Holes".



Prof. Ramesh Narayan's talk on 'Black Holes'.

Prof. Ramesh Narayan explaining the mysteries of our Galaxy.

14. AWARDS / HONORS

Prof. K. A. Suresh has been awarded "Vth Bipinpal Das Memorial Oration Award (2014)" by Science Academy of the North East, Guwahati, India.

15. LIST OF SCIENTISTS AND RESEARCHERS

	Name	Designation
1.	Prof. K. A. Suresh	Scientist of Eminence
2.	Dr. S. Krishna Prasad	Scientist F
3.	Dr. Geetha G. Nair	Scientist D
4.	Dr. D. S. Shankar Rao	Scientist D
5.	Dr. Veena Prasad	Scientist D
6.	Dr. C. V. Yelamaggad	Scientist D
7.	Dr. P. Viswanath	Scientist D
8.	Dr. S. Angappane	Scientist D
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.	Dr. Nani Babu Palakurthy	Research Associate
15.	Ms. Rashmi Prabhu	Senior Research Fellow*
16.	Ms. N. G. Nagaveni	Senior Research Fellow*
17.	Ms. R. Bhargavi	Senior Research Fellow*
18.	Ms. T. Shilpa Harish	Senior Research Fellow
19.	Mr. M. Vijay Kumar	Senior Research Fellow
20.	Ms. R. Rajalakshmi	Senior Research Fellow
21.	Mr. Nagaiah Kambhala	Senior Research Fellow
22.	Ms. H. N. Gayathri	Senior Research Fellow
23.	Ms. P. Lakshmi Madhuri	Senior Research Fellow
24.	Ms. S. Vimala	Senior Research Fellow
25.	Mr. K. Bramhaiah	Senior Research Fellow
26.	Ms. M. Monika	Junior Research Fellow
27.	Ms. P. Srividya	Junior Research Fellow
28.	Mr. B. N. Veerabhadraswamy	Junior Research Fellow
29.	Mr. Chandan Kumar	Junior Research Fellow
30.	Mr. Arup Sarkar	Junior Research Fellow
31.	Ms. Priya Madhuri	Junior Research Fellow
32.	Mr. Nivedh Jayanth	Project Assistant (up to 25.04.2014)
33.	Ms. Usha Parvathi .M.	Project Assistant (up to 03.02.2015)
34.	Mr. B. Kamaliya	Project Assistant

** Since submitted the thesis and left.*

16. ADMINISTRATIVE STAFF

	Name	**Designation**
1.	Shri Subhod M. Gulvady	Administrative Officer
2.	Shri Vivek Dubey	Accounts Officer
3.	Shri K. R. Shankar	Consultant in Accounts (Up to 30.04.2013)
4.	Shri L. Chandra Sekhar	Maintenance Engineer (Up to 31.07.2014)
5.	Smt . P. Nethravathi	Office Superintendent
6.	Dr. Sanjay K. Varshney	Technical Assistant

7.	Smt. Sandhya D. Hombal	Technical Assistant
8.	Shri M. Jayaram	U.D.C.
9.	Smt. Nayana .J.	Library Assistant
10.	Shri Manjunatha .V.	Admn. Assistant
11.	Shri Samuel V. Hebick	Support Staff
12.	Shri Jayaprakash V.K.	Support Staff
13.	Shri Ningappa K.	Support Staff
14.	Shri Prahlad D.G.	Support Staff

17. PUBLICATIONS DURING 2014-2015

Technical Reports / Monographs / Text Book, etc:

1. Introduction to Crystal Growth: Principles and Practice. H.L. Bhat, Published on October 24, 2014 by CRC Press, Reference - 346 Pages - 186 B/W Illustrations, ISBN 9781439883303 - CAT# K13924
2. Invited article, Conference Report – ILCC 2014, K. A. Suresh, *Liquid Crystals Today*, **24**,56, (2015)

Book Chapter

1. Liquid crystals under high pressure, S. Krishna Prasad, in **The Encyclopedia of Materials: Science and Technology**, Eds. S. Mahfoudh & M. Nicholls (Elsevier Science Ltd., Amsterdam), accepted

Publications in Refereed Journals

1) Photo-driven giant reduction of the Frank elastic constants in a bent-core nematic liquid crystal, P. Lakshmi Madhuri, S. Krishna Prasad, Uma S. Hiremath, and C. V. Yelamaggad, *Appl. Phys. Lett.* **104,** pp 241111-1-5 (2014). (Impact Factor 3.515)

2) Competition between anisometric and aliphatic entities: An unusual phase sequence with the induction of a phase in an alkane–liquid crystal binary system M. Vijay Kumar, S. Krishna Prasad, D. S. Shankar Rao and P. K. Mukherjee, *Langmuir* **30**, pp 4465–4473 (2014). (Impact Factor 4.384)

3) Supergelation via purely aromatic $\pi-\pi$ driven self-assembly of pseudodiscotic oxadiazole mesogens, A.P. Sivadas, N. S. S. Kumar, D. D. Prabhu, S. Varghese, S. Krishna Prasad, D. S. Shankar Rao and Suresh Das, *J. Am. Chem. Soc.*, **136**, pp 5416–5423 (2014). (Impact Factor 10.677)

4) Influence of polarization-tilt coupling on the ferroelectric properties of smectic gels, S. Vimala, Geetha G. Nair, S. Krishna Prasad, Uma S. Hiremath and C. V. Yelamaggad, *Soft Matter,* **10,** pp 5905-5915 (2014). (Impact Factor 4.151)

5) Columnar self-assembly of star-shaped luminescent oxadiazole and thiadiazole derivatives, S. K. Pathak, R. K. Gupta, S. Nath, D. S. Shankar Rao, S. Krishna Prasad, and A. S. Achalkumar, *J. Mater. Chem.C* **3**, pp 2940-2952 (2015). (Impact Factor 6.626)

6) Stable ferroelectric liquid crystals derived from salicylaldimine-core, B. N. Veerabhadraswamy, D. S. Shankar Rao, and C. V. Yelamaggad, *J. Phys. Chem. B*, **119,** 4539–4551 (2015). (Impact Factor 3.377)

7) Optically active, three-ring calamitic liquid crystals: the occurrence of frustrated, helical and polar fluid mesophases, B. N. Veerabhadraswamy, D. S. Shankar Rao, S. Krishna Prasad and C. V. Yelamaggad, *New J. Chem.*, **39,** 2011 (2015). (Impact Factor 3.159)

8) Viscoelastic behavior of a binary system of strongly polar bent-core and rodlike nematic liquid crystals, Srividhya Parthasarathi, D. S. Shankar Rao, K. Fodor Csorba, and S. Krishna Prasad, *J. Phys. Chem. B*, **118,** pp 14526–14535 (2014). (Impact Factor 3.377)

9) Non-symmetric dimers comprising chalcone and cholesterol entities: an investigation on structure–property correlations, A. S. Achalkumar, D. S. Shankar Rao and C. V. Yelamaggad, *New J. Chem*., **38,** pp 4235—4248 (2014). (Impact Factor 3.159)

10) New 4-(2-(4-alkoxyphenyl)-6-methoxypyridin-4-yl)benzonitriles: Synthesis, liquid crystalline behavior and photo physical properties, T. N. Ahipa, V. Kumar, D. S. Shankar Rao, S. Krishna Prasad and A. V. Adhikari, *CrystEngComm.*, **16**, 5573–5582 (2014). Impact Factor 3.879

11) A charge transfer complex nematic liquid crystalline gel with high electrical conductivity, R. Bhargavi, Geetha G. Nair, S. Krishna Prasad, R. Majumdar, and Braja G. Bag, *J. Appl. Phys.* **116**, 154902 (2014)

12) Self-organization properties of homomeric dipeptides derived from valine, Rashmi Prabhu, C. V. Yelamaggad and G. Shanker, *Liq. Cryst.*, **41**, 1008-1016 (2014) (Impact factor 2.35)

13) Studies of intermolecular hydrogen bonded complex of butyloxy benzoic acid and dipyridyl ethylene, A. Sambyal, G. Kour, S. Sharma, R. K. Bamezai, S. Anthal, V. K Gupta, R. Kant and C. V. Yelamaggad.. *Mol. Cryst. Liq. Cryst.*, **608**, 135–145 (2015) (Impact factor 0.49)

14) Effect of cations on condensation of a mesogenic amphiphilic molecule at the air–aqueous electrolyte interface, Shilpa Harish T and P. Viswanath, *Phys. Chem. Chem. Phys.*, **16**, 1276-1282 (2014). (Impact factor: 4.198)

15) Dislocations and metastable chevrons in the electroconvective inplane normal roll state of a bent core nematic liquid crystal, K. S. Krishnamurthy, P. Tadapatri and P. Viswanath, *Soft Matter*, **10**, 7316–7327 (2014). (Impact factor: 4.151)

16) Breaking the symmetry of ions at the air–water interface, E. Brandes, P. Karageorgiev, P. Viswanath and H. Motschmann, *J. Phys. Chem. C*, **118** (4), 26629–266233 (2014). (Impact factor: 4.835)

17) Anisotropic magnetotransport properties of $La_{0.67}Sr_{0.33}MnO_3$ thin film, N. Kambhala, S. Angappane, *Physics Procedia,* **54**, 164-167 (2014).

18) Effect of thickness on the structural and optical properties of sputtered ZnO and ZnO:Mn thin films, R. Rajalakshmi, S. Angappane, *J. Alloy Compd.* **615**, 355-362 (2014).

19) Three dimensional branched gold nanostructures on reduced graphene oxide films formed at a liquid/liquid interface, K. Bramhaiah, Vidya N. Singh and Neena S. John, *Part. Part. Syst. Charact.* (Wiley VcH), **31,** 1168–1174 (2014).

20) Spatiotemporal character of the Bobylev-Pikin flexoelectric instability in a twisted nematic bent-core liquid crystal exposed to very low frequency fields K. S. Krishnamurthy *Phys. Rev. E* **89**, 052508 (2014)

21) Investigation of dielectric relaxation, Jahn-Teller distortion, and magnetic ordering in Y substituted Pr1-xYxMnO3 (0.1 <= x <= 0.4) Ruchika Yadav, Harikrishnan S.Nair, Amit Kumar, Shilpa Adiga, H.L.Bhat, S.M.Yusuf and Suja Elizabeth, *Jour. of Appl. Phys.,* **117**, 093903 (2015).

In press

1) Fast photoluminescence switching in the nematic phase of calamitic-discotic composites, P. Lakshmi Madhuri, D.S. Shankar Rao, C. V. Yelamaggad and A.S. Achalkumar, and S. Krishna Prasad, *Advanced Optical Materials*, (in press)

2) Enhancement of electrical conductivity of a liquid crystal-gold nanoparticle composite by a gel network of aerosil particles, B. Kamaliya, M. Vijay Kumar, C. V. Yelamaggad, and S. Krishna Prasad, *Appl. Phys. Lett.* (in Press)

3) Synthesis and aggregation behaviour of luminescent mesomorphic zinc(II) complexes with 'salen' type asymmetric Schiff base ligands , S. Chakraborty, C. R. Bhattacharjee, P. Mondal, S. Krishna Prasad and D. S. Shankar Rao, *Dalton Trans.* (in press).

4) Self-assembly of luminescent N-annulated perylene tetraesters into fluid columnar phases R.K.Gupta, S.K.Pathak, B.Pradhan, D. S. Shankar Rao, S.Krishna Prasad and A. S. Achalkumar, *Soft Matter*, (in press).

5) Flexo-dielectro-optical spectroscopy as a method of studying nanostructured nematic liquid crystals, M. Vijay Kumar, S. Krishna Prasad, Y. Marinov, L. Todorova, A.G.Petrov, *Mol. Cryst. Liq. Cryst.* (in press).

6) Tuning the thermotropic properties of liquid crystalline p-substituted aroylhydrazones, H. K. Singh, S. K. Singh, R. Nandi, M. K. Singh, Vijay Kumar, R. K. Singh, S. Krishna Prasad, D.S. Shankar Rao and B. Singh, *RSC Adv.*, (in press).

7) Low cost, ultra-thin films of reduced graphene oxide-ag nanoparticle hybrids as SERS based excellent dye sensors, C. Kavitha, K. Bramhaiah, Neena S. John, B.E. Ramachandran, *Chem.Phys.Lett.* (in press)

Publications in Conference Proceedings

1. Photo-stimulated electro-optic response of liquid-crystalline system with trans-cis photo-isomerizable agent, G. B. Hadjichristov, Y. G. Marinov, C. V. Yelamaggad and S. K. Prasad, *J. Phys.: Conf. Ser.*, **558,** 012026 (2014).
2. Resistive Switching Behavior of RF Magnetron Sputtered ZnO Thin Films" R. Rajalakshmi and S. Angappane, *AIP Conference Proceedings* (in press) (2015).
3. Reduced graphene oxide based silver sulfide hybrid films formed at a liquid/liquid interface, K. Bramhaiah and Neena S. John, *AIP Conf. Proc.*, **1591**, 366-368 (2014).

CENTRE FOR NANO AND SOFT MATTER SCIENCES
BENGALURU

STATEMENT OF ACCOUNTS
FOR THE YEAR 2014-2015
AND
THE BALANCE SHEET AS ON 31.03.2015

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

No. 618, 75th Cross, 6th Block,
Rajajinagar, Bengaluru-560 010
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Email: grvauditor@gmail.com
1grvenkat@gmail.com

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

We have audited the attached Balance Sheet of **Centre for Nano and Soft Matter Sciences** as at March 31, 2015, the Income & Expenditure Account for the year ended on that date and the Receipts and Payment account for the year ended on that date annexed thereto. These financial statements are the responsibility of the management of Centre for Nano and Soft Matter Sciences. Our responsibility is to express an opinion on these financial statements based on our audit.

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

We report that:

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

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

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

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

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

...............2

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

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

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

(a) in the case of Balance Sheet, of the state of affairs of the Centre for Soft Matter Research as at March 31, 2015; and

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

For M/s G R Venkatanarayana
Chartered Accountants

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

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

Place : Bangalore
Date: 20.05.2015

CENTRE FOR NANO AND SOFT MATTER SCIENCES
JALAHALLI, BANGALORE - 560 013

BALANCE SHEET AS AT 31ST MARCH, 2015

(Amount in Rupees)

I. CORPUS / CAPITAL FUND AND LIABILITIES	SCH	31.03.2015	31.03.2014
CORPUS / CAPITAL FUND	1	17,05,78,419	15,98,63,630
RESERVES AND SURPLUS	2	-	-
EARMARKED PROJECTS FUNDS	3	1,05,85,244	1,28,45,073
SECURED LOANS AND BORROWINGS	4		
UNSECURED LOANS AND BORROWINGS	5	-	-
DEFERRED CREDIT LIABILITIES	6	-	-
CURRENT LIABILITIES AND PROVISIONS	7	26,39,920	22,16,464
TOTAL		**18,38,03,583**	**17,49,25,167**

II APPLICATION OF FUNDS/ASSETS	SCH	31.03.2015	31.03.2014
FIXED ASSETS	8	11,28,58,272	10,61,65,204
INVESTMENTS - FROM EARMARKED/ENDOWMENT FUNDS	9	-	-
INVESTMENTS - OTHERS	10	-	-
CURRENT ASSETS, LOANS, ADVANCES ETC.,	11	7,09,45,311	6,87,59,963
TOTAL		**18,38,03,583**	**17,49,25,167**
NOTES ON ACCOUNTS	24		

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

(PROF. G.U. KULKARNI)
DIRECTOR

(VIVEK DUBEY)
ACCOUNTS OFFICER

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

M/s. G.R. VENKATANARAYANA
Chartered Accountants
616, 75th Cross, 6th Block
Rajajinagar, BANGALORE 560 010

PLACE :BANGALORE
DATE : 20.05.2015

CENTRE FOR NANO AND SOFT MATTER SCIENCES
JALAHALLI, BANGALORE - 560 013

INCOME AND EXPENDITURE ACCOUNT FOR THE YEAR ENDED 31ST MARCH, 2015

(Amount in Rupees)

A - INCOME	SCH	2014-15	2013-14
Income from Sales / Services	12	-	-
Grants / Subsidies:	13	5,11,67,000	5,60,00,000
Fees / Subscriptions	14	-	-
Income from Investments(income on investments from earmarked / endowment Funds)	15	-	-
Income from Royalty, Publications etc.,	16	-	-
Interest earned	17	70,15,454	45,47,627
Other Income	18	75,539	7,03,190
Increase / (decrease) in stock of finished goods and work-in-progress	19	-	-
TOTAL (A)		**5,82,57,993**	**6,12,50,817**

B - EXPENDITURE			
Establishment Expenses	20	2,10,10,729	2,01,89,426
Other Administrative Expenses etc.,	21	1,05,57,536	1,41,29,955
Expenditures on Grants, Subsidies etc.,	22	2,38,66,719	3,16,43,171
Interest	23	-	-
TOTAL (B)		**5,54,34,984**	**6,59,62,552**
C.BALANCE BEING SURPLUS / (DEFICIT) (A-B)		28,23,009	(47,11,735)
D. Less: Prior Period Adjustment		-	1,790
E. SURPLUS / (DEFICIT) CARRIED TO CORPUS / CAPITAL FUND (C+D)		**28,23,009**	**(47,09,945)**
NOTES ON ACCOUNTS	24		

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

(PROF. G.U. KULKARNI)
DIRECTOR

Vivek Dubey
(VIVEK DUBEY)
ACCOUNTS OFFICER

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

M/s. G.R. VENKATANARAYANA
Chartered Accountants
[illegible] 6th Block
[illegible] 560 010

PLACE :BANGALORE
DATE : 20.05.2015

CENTRE FOR NANO AND SOFT MATTER SCIENCES
JALAHALLI, BANGALORE - 560 013

RECEIPTS AND PAYMENTS FOR THE YEAR ENDED 31ST MARCH, 2015

(Amount in Rupees)

RECEIPTS		For the year 14-15	For the year 13-14
1 Opening Balances			
1) Cash in Hand		Nil	Nil
2) Bank Balances		2,41,58,925	
a) Indian Bank	87337		5,63,293
b) State Bank of India	21014220		36,30,953
c) State Bank of Mysore 1	3049777		16,44,506
d) State Bank of Mysore 2	4845		4,945
e) Bank of India	1648		1,584
f) Union Bank of India	1098		1,055
II Grants-in-aid from DST, Govt of India		51167000	5,60,00,000
III Interest Earned		69,40,430	
a) On Savings Bank Accounts	2399863		5,75,099
b) On Fixed/Term Deposits	4540567		39,72,528
IV Other Income		19,119	
a) Stale cheque			75,784
b) License Fee	15993		20,600
c) Miscellaneous Receipts	3126		8,952
V Other Recoveries etc.,			
A) Earnest Money Deposit & Security Deposit		10,11,697	3,61,645
B)		35,18,123	
i) C. P F. Employees Contribution	500788		4,51,039
ii) Income Tax Deducted at source from staff, contractor & rent and Professional Tax	15,49,957		16,49,774
iii) Advance to suppliers/others etc.,	124571		10,10,077
iv) Staff Advance Recovery	806536		5,52,493
v) CPF Advance Recovery			49,980
vi) New Pension Scheme Tier -1	536271		4,65,997
C)		1,27,184	
i) Establishment Receipts	113528		1,11,900
ii) Other Administrative Receipts	13656		6,46,901
VI Investments			
a) Fixed/Term deposits matured	2,32,63,066	2,32,63,066	6,87,61,239
b) Sale of Fixed Asset	5,500	5,500	40,000
VII Grants/Financial Assistances received for Earmarked Projects	10,03,645	10,03,645	74,01,000
TOTAL		11,12,14,689	14,80,01,344

PAYMENTS		For the year 14-15	For the year 13-14
I. Establishment Expenses		1,86,00,584	1,79,43,726
II Administrative Expenses		1,03,31,439	1,44,93,234
III Fixed Assets (Additions)		2,35,85,946	3,12,33,386
IV A) Remittances/Refunds etc.,			
a) Earnest Money Deposit & Security Deposit		6,56,847	4,37,391
b) CPF Advance and other			49,980
B) Remittances/Refunds etc.,		59,98,730	
a) C P F Employees Contribution	5,00,788		4,51,039
b) C.P.F. CSMR Contribution	2,77,480		2,69,376
c) Income Tax Deducted at source from staff, contractor & rent and Professional Tax	15,49,957		16,49,774
d) Advance to suppliers/others etc.,	76,849		17,61,766
e) Staff Advances	9,34,623		5,24,251
f) New Pension Scheme Tier 1	10,72,542		9,31,994
g) Telephone Deposit			25,500
V h) Provisions for last year paid	15,71,327		14,35,040
i) Stale cheque	15,164		13,136
Investments			
VI Fixed/Term Deposits made		2,96,09,136	4,65,33,157
VII Earmarked Project Expenses		19,76,762	60,89,669
Closing Balance			
1) Cash in Hand		Nil	Nil
2) Bank Balances		2,04,55,245	
a) Indian Bank	90,878		87,337
b) State Bank of India	1,62,86,328		2,10,14,220
c) State Bank of Mysore (RMV)	40,70,886		30,49,777
d) State Bank of Mysore (Vyalik)	4,295		4,845
e) Bank of India	1,715		1,648
f) Union Bank of India	1.143		1,098
TOTAL		11,12,14,689	14,80,01,344

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

(PROF. G.U. KULKARNI)
DIRECTOR

Vivek Dubey
(VIVEK DUBEY)
ACCOUNTS OFFICER

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

PLACE :BANGALORE
DATE : 20.05.2015

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

CENTRE FOR NANO AND SOFT MATTER SCIENCES
JALAHALLI, BANGALORE - 560 013

SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31ST MARCH, 2015

(Amount in Rupees)

		As at 31.03.2015	As at 31.03.2014
SCHEDULE 1 - CORPUS / CAPITAL FUND:			
As Per Previous Balance Sheet		159863630	148894731
ADD: Fixed Assets purchased during the year(net)		23866719	31643171
		183730349	**180537902**
ADD: Excess of Income over Expenditure for the year		2823009	-4709945
LESS: Depreciation for the year		15974939	15964327
	TOTAL	**170578419**	**159863630**
SCHEDULE 2 - RESERVES AND SURPLUS:	**TOTAL**	-	-
SCHEDULE 3 - EARMARKED / PROJECT FUNDS:	**TOTAL**	**10585244**	**12845073**
(See Annexure A for details)			
SCHEDULE 4 - SECURED LOANS AND BORROWINGS:	**TOTAL**	-	-
SCHEDULE 5 - UNSECURED LOANS AND BORROWING	**TOTAL**	-	-
SCHEDULE 6 - DEFERRED CREDIT LIABILITIES:	**TOTAL**	-	-
SCHEDULE 7-CURRENT LIABILITIES & PROVISIONS:			
A) CURRENT LIABILITES:			
1) Statutory Liabilities		-	-
2) Other Liabilities		970979	569353
3) Stale Cheque		60620	75784
	TOTAL (A)	**1031599**	**645137**
B) **PROVISIONS:**			
Salaries & Allowances		1608321	1571327
	TOTAL (B)	**1608321**	**1571327**
	TOTAL (A+B)	**2639920**	**2216464**
SCHEDULE 8 - FIXED ASSETS	**TOTAL**	**112858272**	**106165204**
SCHEDULE 9- INVESTMENTS FROM EARMARKED / ENDOWMENT FUNDS:		-	-
SCHEDULE 10 - INVESTMENTS - OTHERS:		-	-
SCHEDULE 11 - CURRENT ASSETS,LOANS, ADVANCES:			
A) CURRENT ASSETS:			
1) Inventories		-	-
2) Sundry Debtors:		-	-
3) Cash Balances in Hand(including Cheques/Drafts and Imprest)		-	-
4) Bank Balances:- Nationalised Banks			
a. Term Deposit Receipts (includes margin money)		49744268	43398198
b. Current Account : SBM Vyalikaval		4295	4845
c. Savings Accounts:			
Bank of India (Malleswaram)		1715	1648
Union Bank of India (Malleswaram)		1143	1098
Indian Bank (BEL Road)		90878	87337
SBI (Jalahalli)		16286328	21014220
SBM (RMV Extn)		4070886	3049777
	TOTAL (A)	**70199513**	**67557123**

B) LOANS,ADVANCES AND OTHER ASSETS:		
1) Loans	-	-
2) Advances and Other amounts recoverable in Cash or in kind or for value to be received:	272857	484705
a) K P T C L Deposit (SERC/CLCR)	362590	362590
b) Telephone	87000	87000
3) Claims Receivable from SERB	-	268545
4) TDS By Bank/ BESCOM	23351	-
TOTAL (B)	**745798**	**1202840**
TOTAL (A+B)	**70945311**	**68759963**

SCHEDULE 12 - INCOME FROM SALES / SERVICES: TOTAL	-	-

SCHEDULE 13 - GRANTS / SUBSIDIES:

(Irrevocable Grants & Subsidies Received)		
Dept of Science & Techonolgy Government of India **TOTAL**	**51167000**	**56000000**

SCHEDULE 14 - FEES / SUBSCRIPTIONS: TOTAL	-	-
SCHEDULE 15 - INCOME FROM INVESTMENTS: TOTAL	-	-
SCHEDULE 16 - INCOME FROM ROYALTY, PUBLICATIONS ETC.: TOTAL	-	-

SCHEDULE 17 - INTEREST EARNED:

1) On Term Deposits - Nationalised Banks	4615591	3972528
2) On Savings Accounts - Nationalised Bank	2399863	575099
TOTAL	**7015454**	**4547627**

SCHEDULE 18 - OTHER INCOME:

Licence Fee/Hostel Room rent recovery	15993	20600
Miscellaneous Income	57835	61590
Project Overhead Recovered		621000
Interest on Advance	1,711	-
TOTAL	**75539**	**703190**

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

SCHEDULE 20 - ESTABLISHMENT EXPENSES:

1) Salaries, Allowance and Wages to Staff	17133480	15730447
2) Medical Expenses Reimbursed	16100	61572
3) Bonus	35567	37006
4) Fellowship & Book Grant	3825582	4360401
TOTAL	**21010729**	**20189426**

SCHEDULE 21 - OTHER ADMINISTRATIVE EXPENSES,ETC:

Chemicals, Glasswares & Consumables etc.,	1666900	2319514
Duties & Taxes	106380	155571
Electricity & Water Charges	1653511	1867058
Fees & Professional charges	257633	197957
Foreign Travel	152695	139139
Fuel Charges for Genset	33612	99789
Hospitality Charges	95867	136133
House Keeping Charges	847003	1216234
Journals & Periodicals	41736	924049
Foreign Exchange Fluctuation	6,094	-
Liveries/Uniform	22370	20049
Conveyance Charges	385672	418171

Vivek Dubey

Man Power Supply Expenses	96123	47565
Other Miscellaneous Charges / Bank Charges	89280	117603
Advertisement and Pulbilcity Charges	87247	623254
Printing & Stationery	374679	383861
Registration & Renewals	21371	127260
Rent & Insurance	415748	476125
Repairs & Maintenance	2449388	2641912
Security Charges	1124061	1036360
Seminar and Conferences	152183	118428
Telephone Charges	288074	272889
Travel Expenses	96459	511047
Testing (N.M.R.) & Sample analysis charges	93450	279987
TOTAL	**10557536**	**14129955**
SCHEDULE 22 - EXPENDITURE ON GRANTS, SUBSIDIES ETC: (Fixed assets)(net)	**23866719**	**31643171**
SCHEDULE 23 - INTEREST:	-	-

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

(PROF. G.U.KULKARNI)
DIRECTOR

(VIVEK DUBEY)
ACCOUNTS OFFICER

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

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

PLACE :BANGALORE
DATE : 20.05.2015

CENTRE FOR NANO AND SOFT MATTER SCIENCES
JALAHALLI, BANGALORE - 560 013

SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31ST MARCH, 2015

Annexure - A to Schedule 3

(Amount in Rupees)

SCHEDULE 3 - EARMAR FUNDS	PROJECT / WISE BREAKUP SERC	SERC (2004-05)	SERC (CVY1)	INDO-US	INDO-US (SKP)	INDO - JAPAN	CSIR (NMITLI)	CSIR (SK)	CSIR (CVY)	CSIR !162_CVY	SERC HL Bhat	WOS-A-1 (USH)	SERB (SKP)	SERB (SA)	SERB (NSJ)	INDO-Bulgerian (SKP)	SERB (GGN)	SERB (CVY)	WOS-A-2 (USH)	CURRENT YEAR TOTAL	PREVIOUS YEAR
a) Opening Balance of th	1390385	74813	594098	371810	91365	175319	553773	14539	9223	83112	176462	-168546	2248483	842258	1305129	216780	3831285	552955	481830	12845073	8968596
b) Additions to the Funds																					
i) Grants	-	-	-	-	-									200000			500000	300000		1000000	7401000
ii) Income from investment made	-	-	-	-	-																
TOTAL (a+b)	1390385	74813	594098	371810	91365	175319	553773	14539	9223	83112	176462	-168546	2248483	1042258	1305129	216780	4331285	852955	481830	13845073	16369596
c) Utilisation/Expenditure towards objectives of Funds:																					
i) Capital Expenditure																					
Fixed Assets	-	-	-	-	-																
Others																					
ii) Revenue Expenditure																					
Salaries, Wages anc	-	-	-	-	-								144000		24000	125606	133286	356871	420000	1203763	802829
Consumables	-	-	-	-	-								146140	31415	231484		109773	154600	40390	713802	507494
Depreciation	110220	11222	89115	7498	13712		83067	2180	1427	12467			319938	143168			548250			1342264	1593200
Overheads	-	-	-	-	-																621000
Grant Refunded	-	-	-	-	-																
TOTAL (c)	110220	11222	89115	7498	13712		83067	2180	1427	12467	-	-	610078	174583	255484	125606	791309	511471	460390	3259829	3524523
NET BALANCE AT THE YEAR END (a+b-c)	1280165	63591	504983	364312	77653	175319	470706	12359	7796	70645	176462	-168546	1638405	867675	1049645	91174	3539976	341484	21440	10585244	12845073

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CENTRE FOR NANO AND SOFT MATTER SCIENCES
JALAHALLI, BANGALORE - 560 013

SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31ST MARCH, 2015

SCHEDULE - 8 : FIXED ASSETS

(Amount in Rupees)

DESCRIPTION	W.D.V. as on 01.04.2014	Additions during the year			Total	Assets sold / replaced during the	Total as on 31.03.2015	Rate of Dep.	Depreciation Full Rate	Dep. For Addition o <180 Days	Total Depreciation for the year	W.D.V. as on 31.03.2015
		>180 days	<180 Days	Total additions								
A. CNSMS :												
CIVIL WORKS												
Aluminium Partitions	12,38,842	-	-	-	12,38,842	-	12,38,842	10	1,23,884	-	1,23,884	11,14,958
Brick Base(Partitions)	1,10,374	-	-	-	1,10,374	-	1,10,374	10	11,037	-	11,037	99,337
Construction of Cycle Stand	43,549	-	-	-	43,549	-	43,549	10	4,355	-	4,355	39,194
Construction of Shed	44,879	-	-	-	44,879	-	44,879	10	4,488	-	4,488	40,391
Vinyl Flooring	2,14,777	-	-	-	2,14,777	-	2,14,777	10	21,478	-	21,478	1,93,299
Other Miscellaneous Works	14,23,711	-		-	14,23,711	-	14,23,711	10	1,42,371	-	1,42,371	12,81,340
BUILDING (Main & Annexe)	58,61,587	-	2,54,211	2,54,211	61,15,798	-	61,15,798	10	5,86,159	-	5,86,159	55,29,639
ELECTRICAL INSTALLATIONS												
Air Conditioner	6,02,792	37,990	35,950	73,940	6,76,732	2,000	6,74,732	15	95,817	-	95,817	5,78,915
Computers	1,86,922	-	2,06,645	2,06,645	3,93,567	-	3,93,567	60	1,12,153	61,994	1,74,147	2,19,420
Fume Cupboard	1,47,480	-	-	-	1,47,480	-	1,47,480	10	14,748	-	14,748	1,32,732
Generator Set	5,15,978	-	-	-	5,15,978	-	5,15,978	15	77,397	-	77,397	4,38,581
FURNITURE & FIXTURES												
Carpentary Works	4,39,820	48,265	8,587	56,852	4,96,672	-	4,96,672	10	48,809	429	49,238	4,47,434
Furniture & Fixtures	12,81,398	-	29,781	29,781	13,11,179	-	13,11,179	10	1,28,140	1,489	1,29,629	11,81,550
GENERAL EQUIPMENTS												
Equipment	57,01,922	-	3,30,058	3,30,058	60,31,980	2,500	60,29,480	15	8,54,913	24,754	8,79,667	51,49,813
Workshop Equipment	93,757	-	-	-	93,757	-	93,757	15	14,064	-	14,064	79,693
SCIENTIFIC EQUIPMENTS	7,90,12,611	10,08,849	2,19,11,883	2,29,20,732	10,19,33,343	1,000	10,19,32,343	15	1,20,03,069	16,43,391	1,36,46,460	8,82,85,883
Total - (A)	**9,69,20,399**	**10,95,104**	**2,27,77,115**	**2,38,72,219**	**12,07,92,618**	**5,500**	**12,07,87,118**		**1,42,42,882**	**17,32,057**	**1,59,74,939**	**10,48,12,179**
B. SERC PROJECT:												
Electrical Installation	66,825	-	-	-	66,825	-	66,825	15	10,024	-	10,024	56,801
Equipment	6,67,748	-	-	-	6,67,748	-	6,67,748	15	1,00,162	-	1,00,162	5,67,586
Cycle	224	-	-	-	224	-	224	15	34	-	34	190
Total - (B)	**7,34,797**	-	-	-	**7,34,797**	-	**7,34,797**		**1,10,220**	-	**1,10,220**	**6,24,577**
C. INDO US PROJECT:												
Equipment	42,106	-	-	-	42,106	-	42,106	15	6,316	-	6,316	35,790
Temperature Controller	3,215	-	-	-	3,215	-	3,215	15	482	-	482	2,733
Cell Fabrication	4,665	-	-	-	4,665	-	4,665	15	700	-	700	3,965
Total - (C)	**49,986**	-	-	-	**49,986**	-	**49,986**		**7,498**	-	**7,498**	**42,488**
D. INDO US (SKP) PROJECT:												
Equipment	91,412	-	-	-	91,412	-	91,412	15	13,712	-	13,712	77,700
Total - (D)	**91,412**	-	-	-	**91,412**	-	**91,412**		**13,712**	-	**13,712**	**77,700**
E. CSIR (NMITLI) PROJECT:												
Equipment	5,53,772	-	-	-	5,53,772	-	5,53,772	15	83,066	-	83,066	4,70,706
Computers	1	-	-	-	1	-	1	60	1	-	1	-
Total - (E)	**5,53,773**	-	-	-	**5,53,773**	-	**5,53,773**		**83,067**	-	**83,067**	**4,70,706**
F. CSIR (SK) PROJECT:												
Equipment	14,536	-	-	-	14,536	-	14,536	15	2,180	-	2,180	12,356
Total - (F)	**14,536**	-	-	-	**14,536**	-	**14,536**		**2,180**	-	**2,180**	**12,356**
G. CSIR (CVY) PROJECT:												
Equipment	9,511	-	-	-	9,511	-	9,511	15	1,427	-	1,427	8,084
Total - (G)	**9,511**	-	-	-	**9,511**	-	**9,511**		**1,427**	-	**1,427**	**8,084**
H. SERC (2004-05) PROJECT:												
Equipment	74,813	-	-	-	74,813	-	74,813	15	11,222	-	11,222	63,591
Total - (H)	**74,813**	-	-	-	**74,813**	-	**74,813**		**11,222**	-	**11,222**	**63,591**

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I. SERC (CVY1) PROJECT:												
Equipment	5,94,100	-	-	-	5,94,100	-	5,94,100	15	89,115	-	89,115	5,04,985
Total - (I)	**5,94,100**	-	-	-	**5,94,100**	-	**5,94,100**		**89,115**	-	**89,115**	**5,04,985**
J. CSIR (2162_CVY3) PROJECT:												
Equipment	83,112	-	-	-	83,112	-	83,112	15	12,467	-	12,467	70,645
Total - (J)	**83,112**	-	-	-	**83,112**	-	**83,112**		**12,467**	-	**12,467**	**70,645**
K. SERB (SKP) PROJECT:												
Equipment	20,74,869	58,052	-	58,052	21,32,921	-	21,32,921	15	3,19,938	-	3,19,938	18,12,983
Total - (K)	**20,74,869**	**58,052**	-	**58,052**	**21,32,921**	-	**21,32,921**		**3,19,938**	-	**3,19,938**	**18,12,983**
L. SERB (SA) PROJECT:												
Equipment	8,68,951	85,500	-	85,500	9,54,451	-	9,54,451	15	1,43,168	-	1,43,168	8,11,283
Total - (L)	**8,68,951**	**85,500**	-	**85,500**	**9,54,451**	-	**9,54,451**		**1,43,168**	-	**1,43,168**	**8,11,283**
M. SERB (NSJ) PROJECT:												
Equipment	4,39,945	-	-	-	4,39,945	-	4,39,945	15	-	-	-	4,39,945
Total - (M)	**4,39,945**	-	-	-	**4,39,945**	-	**4,39,945**		-	-	-	**4,39,945**
N. SERB (GGN) PROJECT:												
Equipment	36,55,000	-	-	-	36,55,000	-	36,55,000	15	5,48,250	-	5,48,250	31,06,750
Total - (N)	**36,55,000**	-	-	-	**36,55,000**	-	**36,55,000**		**5,48,250**	-	**5,48,250**	**31,06,750**
Total - B to N	**92,44,805**	**1,43,552**	-	**1,43,552**	**93,88,357**	-	**93,88,357**		**13,42,264**	-	**13,42,264**	**80,46,093**
Grand Total (A to N)	**10,61,65,204**	**12,38,656**	**2,27,77,115**	**2,40,15,771**	**13,01,80,975**	**5,500**	**13,01,75,475**		**1,55,85,146**	**17,32,057**	**1,73,17,203**	**11,28,58,272**

(PROF. G.U. KULKARNI)
DIRECTOR

PLACE : BANGALORE
DATE : 20.05.2015

Vivek Dubey
(VIVEK DUBEY)
ACCOUNTS OFFICER

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

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

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

CENTRE FOR NANO AND SOFT MATTER SCIENCES , JALAHALLI, BANGALORE

SCHEDULES FORMING PART OF THE ACCOUNTS FOR THE YEAR ENDED 31ST MARCH 2015

SCHEDULE 24: NOTES ON ACCOUNTS

A.SIGNIFICANT ACCOUNTING POLICIES:

01. **Accounting Conventions**: The financial statements are drawn up in accordance with historical accounting conventions and on the going concern concept. Cash system is followed to record the Income , Grants and expenditure except Salary for Month of March ,which is recorded as rule no 64 of Central Government Account Receipts and Payment Rules 1983 .

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

02. **Investments** : Investments are stated at cost, Interest from Investments are accounted on cash basis.

03.**Fixed assets** : Fixed assets are stated at written down value. Fixed assets are accounted at cost of acquisition, inclusive of inward freight, duties, taxes and incidental expenses related to acquisition.

04. **Depreciation** : Depreciation on Fixed assets has been provided on Written Down Value Method at rates as per Income Tax Rules 1962. Out of the total amount of Depreciation on fixed assets of ₹ 1,73,17,203/-, depreciation of ₹ 1,59,74,939/- on general fixed assets of the Centre has been debited to capital fund account and the depreciation on assets pertaining to projects amounts to ₹ 13,42,264/- has been debited to the Projects fund account. This system is being followed by the centre in the respective years of acquisition of fixed assets acquired and has been treated as Expenditure on Grants in the Income & Expenditure Account, as a matter of accounting policy, as stated in Note No.6 below.

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

06. **Capital Expenditure :** All Capital Expenditure incurred during the year for purchase of Fixed Assets is charged to Income & Expenditure Account, under the head "Expenditure on Grants/Subsidy". The same is again reflected in Schedule 1 by credit to Capital Fund account.

B.NOTES ON ACCOUNTS:

07. **Contingent Liabilities:** Letters of Credit outstanding as on 31.03.2015 ₹ 24,55,638/- and ₹ - Nil- was outstanding at the end of previous year.

08. Claims against the Centre not acknowledged as debts ₹ Nil (₹ Nil).

09. Foreign currency transactions are translated at the rates prevailing on the date of transaction.

10. Balance shown under Saving Bank Accounts Include amounts held by Bank under " Auto Sweep Accounts".

11. Figures are rounded off to the nearest rupee and figures of previous year have been regrouped and reclassified to conform to that of the current year.

12. Schedules 1 to 24 are annexed to and form an integral part of the Balance Sheet as at 31st March 2015 and the Income and Expenditure Account for the year ended on that date.

As per our report of even date
For M/s G.R.Venkatanarayana
Chartered Accountants

Vivek Dubey

(PROF. G.U. KULKARNI)
DIRECTOR

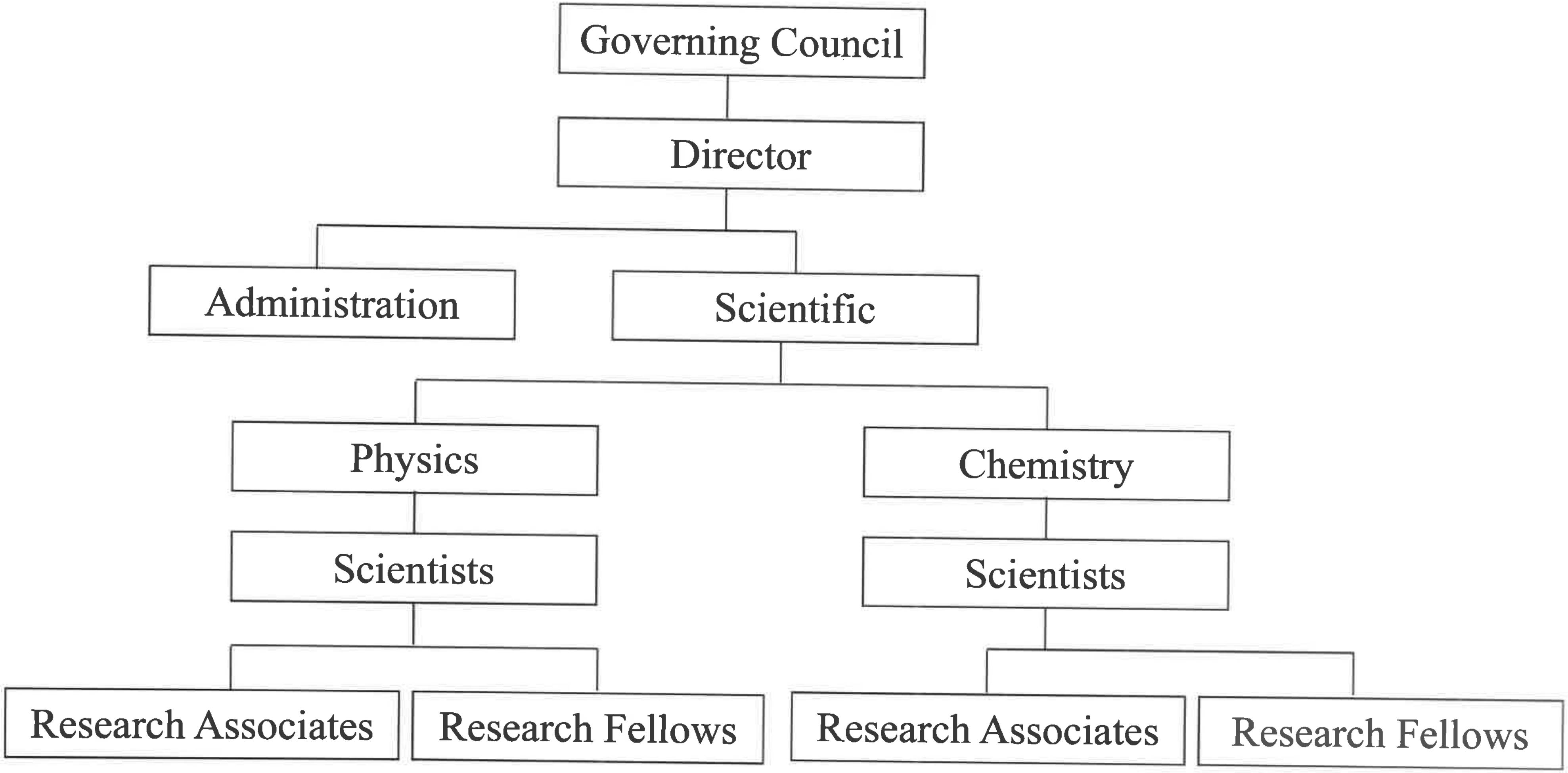
(VIVEK DUBEY)
ACCOUNTS OFFICER

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

M/s. G.R. VENKATANARAYANA
Chartered Accountants
[illegible], 15th Cross, 6th Block
[illegible] BANGALORE 560 010

PLACE : BANGALORE
DATE : 20.05.2015

Centre for Nano and Soft Matter Sciences (CNSMS)
Organisation Chart



नैनो एवं मृदु पदार्थ विज्ञान केंद्र

विज्ञान एवं प्रौद्योगिकी विभाग, भारत सरकार के अधीन एक स्वायत्त संस्था

प्रो। यु. आर. राव मार्ग, जालहल्ली, बेंगलूरु ५६० ०१३

CENTRE FOR NANO AND
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