Newsletter from Indian Crystallographic Association (ICA)

Small Molecule Crystallography in India-A Current Overview

Edited by Dr D. Chopra (Editor of Publications, ICA)

Acknowledgements: I would like to thank the Vice-President of ICA, Professor Rajnikant (Professor of Physics, University of Jammu) for proposing this topic for the current newsletter.

Contents:

1. Introduction

The subject of small molecule crystallography has undergone a major renaissance in the last two decades. Tremendous developments in the area of technology have revolutionized the subject. The existence of advanced light sources, including cryo EM and XFEL's have substantially contributed towards the determination of crystal structures of challenging molecules of chemical and biological origin. The determination of the crystal structure to map the atomic connectivity is of fundamental importance, but in addition, the development of new materials has been achieved by insights from crystallography. Some of the most important applications in small molecule crystallography, includes the following:

- Molecular structure, geometry and intra-/intermolecular interactions
- Absolute structure and configuration
- *In situ* cryocrystallography
- High-Pressure crystallography
- Phase Transition in Solids
- Charge density distribution in molecular crystals
- Computational Approaches in Solid State Chemistry
- Applications of Polymorphism and Cocrystallization in Pharmaceutical Industry
- Structure Property Correlation in Solids

Many research groups are actively involved in different aspects of small molecule crystallography. In particular, the occurrence of different properties in solids, and the role of different intermolecular interactions, present in the crystal, towards the observed property, is an important endeavor with implications in both fundamental and applied sciences.

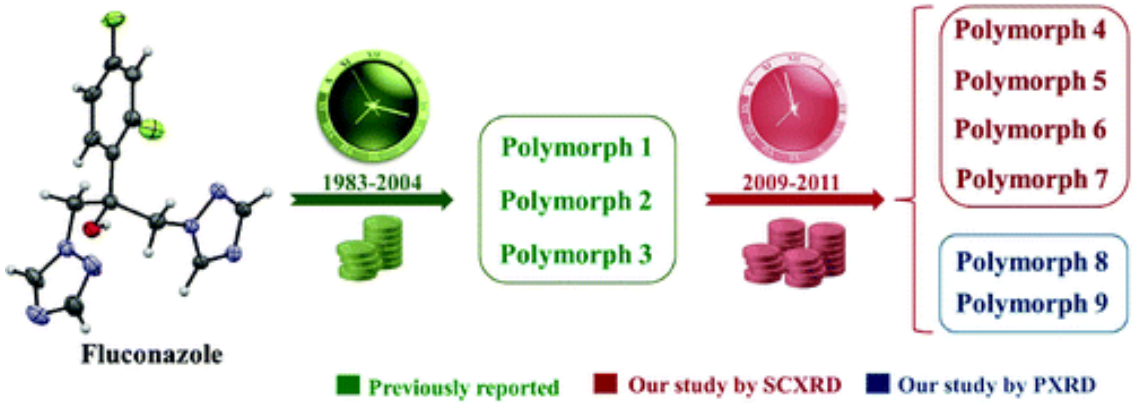
2. Research Groups in Small Molecule Crystallography in India

A brief overview of the different research groups working in the field of small molecule crystallography is as follows:

Angshuman Roy Choudhury,
Department of Chemical Sciences, Indian Institute of Science Education and Research (IISER) Mohali, India.
Email: angshurc@iisermohali.ac.in.

The group of A.R. Choudhury primarily works in the area of intermolecular interactions involving organic fluorine in molecular crystals, polymorphism and cocrystallization in drugs, computational studies of weak interactions and *in situ* crystallization methods in small molecule crystallography.

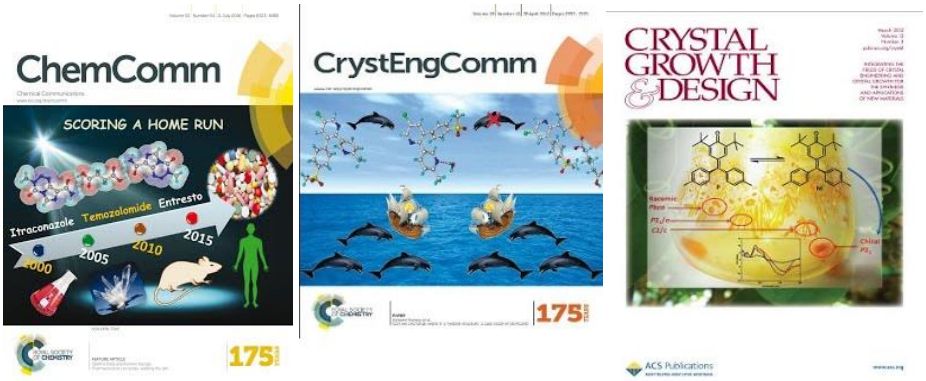
For more details visit: **https://web.iisermohali.ac.in/Faculty/angshurc/.**



A. Nangia,
University of Hyderbad, Prof C.R.Rao Road, Hyderabad 500046, AP, India.
Email: ashwini.nangia@gmail.com

The research group of Prof A. Nangia specializes in the development of drug therapeutics via the method of cocrystallization and polymorphism in pharmaceutically relevant compounds. Such studies are further extended to include solvates, eutectics and alloys, salts, coamorphous solids and host-guest chemistry in the solid state.

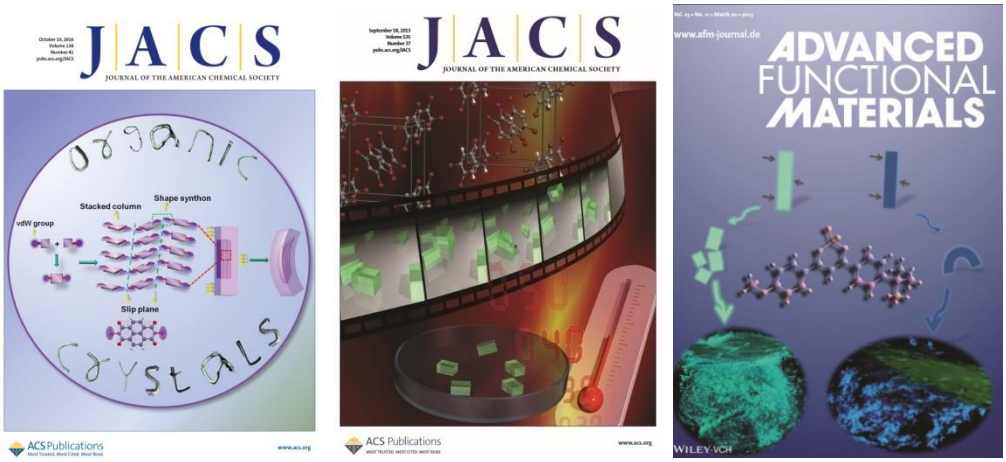
For more details visit: **http://www.anlab.in/**



C. Malla Reddy
Department of Chemistry, IISER (Kolkata), India.
Email: cmallareddy@gmail.com

This research group specializes in the design of flexible organic functional materials utilizing the principles of crystal engineering, solid-state pharmaceutical chemistry, pharmaceutical crystallography, mechanical properties, crystal growth and polymorphism in Active Pharmaceutical Ingredients (APIs). For more details visit:

https://www.iiserkol.ac.in/~ce-group-cmreddy/index.html



Deepak Chopra,
Department of Chemistry, Indian Institute of Science Education and Research (IISER) Bhopal, Bhopal 462066, Madhya Pradesh, India.
Email: dchopra@iiserb.ac.in

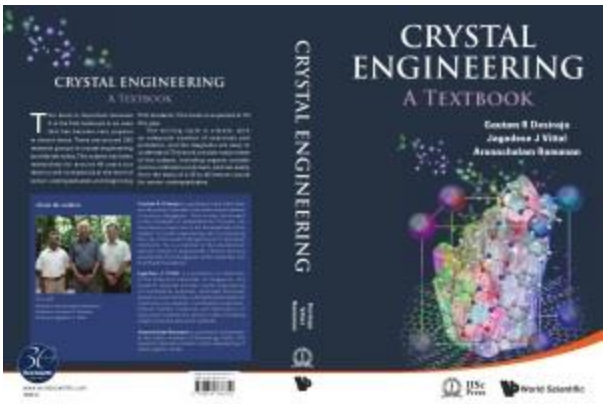
The group of D. Chopra is involved in the investigation of novel non-covalent contacts (for example halogen, chalcogen, carbon and pnictogen bonds) in molecular crystals, polymorphism and cocrystallization, *in situ* crystallization, crystal structure prediction, electron density analysis and mechanical/electrical properties of molecular crystals.

For more details visit: **https://sites.google.com/a/iiserb.ac.in/chemical-crystallography/home**

G. R. Desiraju, SSCU, Indian Institute of Science Bangalore- 560012, India.
Email: gautam.desiraju@gmail.com

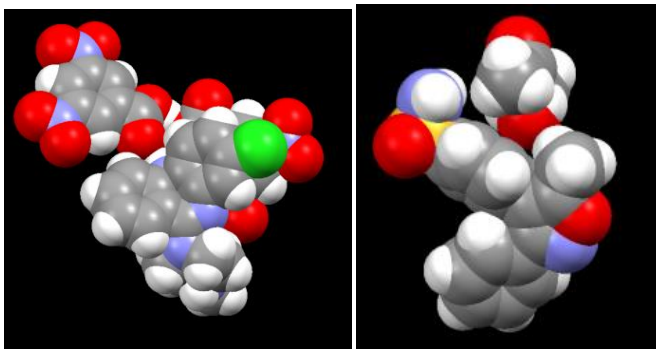
The research interests of this group includes understanding the role of intermolecular interactions to unravel the role of structural landscape in crystal engineering, investigation of halogen bonded systems, synthesis of higher order cocrystals, mechanical properties of molecular crystals, and exploring the physico-chemical properties of polymorphs, salts and hydrates.

For more details visit: **http://desiraju.in/**



H S Yathirajan,
University of Mysore, Manasagangotri, Mysore-570 006, India.
Email: yathirajan@hotmail.com

He has worked on crystal and molecular structure studies of organic haloamines, chalcones, Schiff bases, amides, cocrystals, several heterocyclic compounds and more importantly several pharmaceutical molecules and pharmaceutical intermediates in addition to polymorphism. Currently, his group is working on the salts of heterocyclic compounds and amides of heterocyclic compounds and drug molecules of interest.



K. Biradha,
Department of Chemistry, Indian Institute of Technology, Kharagpur, West Bengal.
Email: kbiradha@yahoo.com.

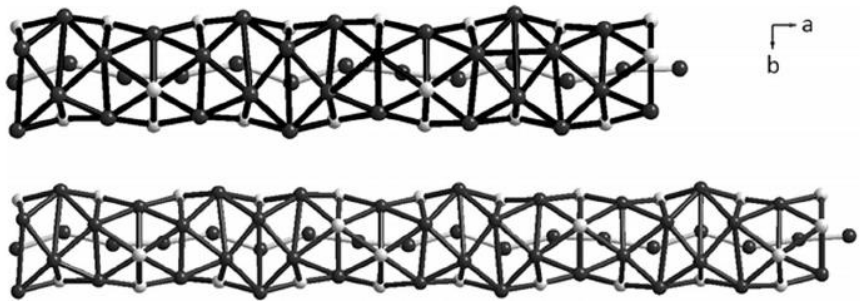
The research group of Prof Biradha aims to design and synthesize several functional materials by the utilization of crystal engineering approaches. This includes extended framework structures (MOFs & COFs), respectively, with high porosity, selective adsorptivity, dye encapsulation and catalysis. Furthermore, the group also explores

hydrogen bonding or supramolecular synthon assisted formation of cocrystals, organic salts and metal assisted organogels for various multifunctional properties. This includes SCSC [2+2] dimerization/polymerization reactions, luminescence and proton conductivity. Furthermore, synthesis of SOFs with intriguing photocatalytic properties for water splitting also is part of their research interests.

For more details visit: **https://www.structuralchemistrylab.com/**

Partha Pratim Jana,
Department of Chemistry, IIT Kharagpur, India.
Email: ppj@chem.iitkgp.ac.in

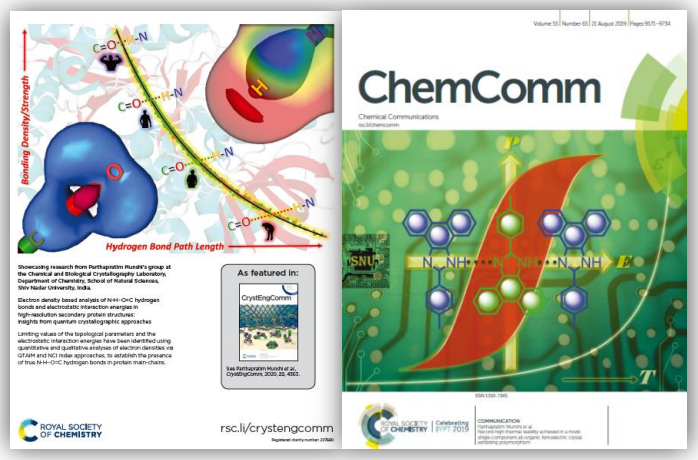
His research interests are in the field of intermetallics as these are susceptible to aperiodic phenomena. Their structure determinations have posed exciting crystallographic problems: superstructures, modulation, twinning, quasicrystalline order, etc. A state-of-the-art crystallographic method, such as superspace modelling is employed to address these challenges. In the recent past, quite a few modulated and complex structures have successfully modelled. To understand the stability of synthesized phases, electronic structure calculations and chemical bonding analysis are performed. Currently the research group has been working on various complexes intermetallic phases in Zn-, Cd- and Pd-rich systems.



Parthapratim Munshi,
Department of Chemistry, School of Natural Sciences, Tehsil, Dadri- 201314, Uttar Pradesh, India.
Email: parthapratim.munshi@snu.edu.in

The group of P. Munshi, primary focuses on quantum crystallography in protein systems and structure property relationship in organic materials. His group extensively uses high-

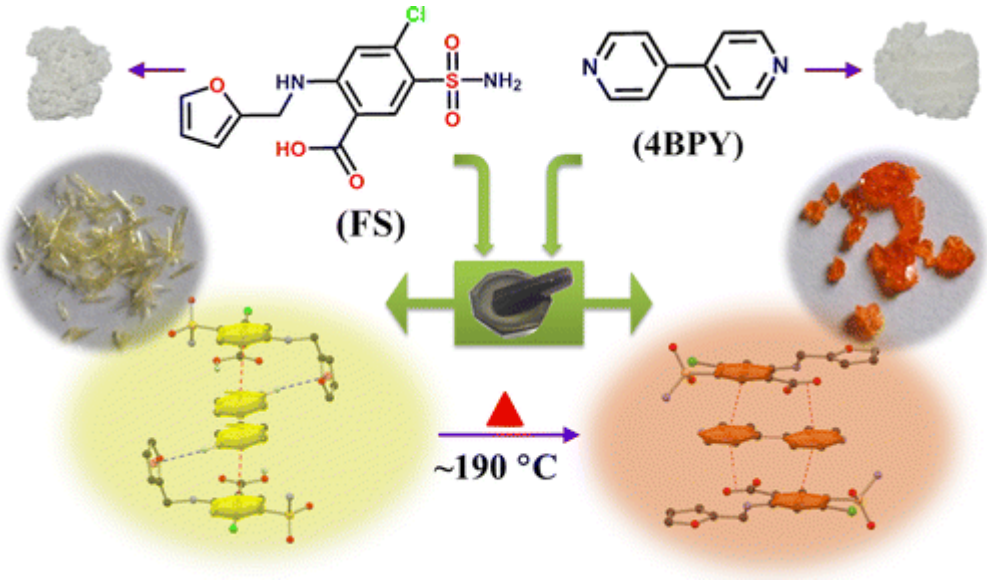
resolution X-ray and neutron diffraction methods for highly accurate structural studies. For further details please visit: **http://parthapratimmunshi.weebly.com/.**



Rajesh G. Gonnade,
Physical and Materials Chemistry Division (CMC Building), CSIR-National Chemical Laboratory, Pune, Mahrasthra, India.
Email: rg.gonnade@ncl.res.in

This research group specializes in the field of crystal engineering and supramolecular chemistry. They exploit the understanding of the intermolecular interactions in designing the materials of desired properties. Currently, his research group is actively involved in the drug polymorphism (polymorph screening), crystal engineering of Active Pharmaceutical Ingredients (APIs) to developed various novel solid phases (cocrystals, salts, eutectics, hydrates, solvates, etc.) with improved physicochemical and biopharmaceutical properties to make better-quality medicines. Dr. Gonnade's research group is involved in investigating reactions in molecular crystals and their correlation using crystal structure analysis (structure-property correlations). Additionally, his research group is engaged in the enantiomeric resolution of racemate (or conglomerate) using simple crystallization (preferential enrichment or preferential crystallization) of important drug intermediates and APIs.

For more details visit: **http://academic.ncl.res.in/rg.gonnade**

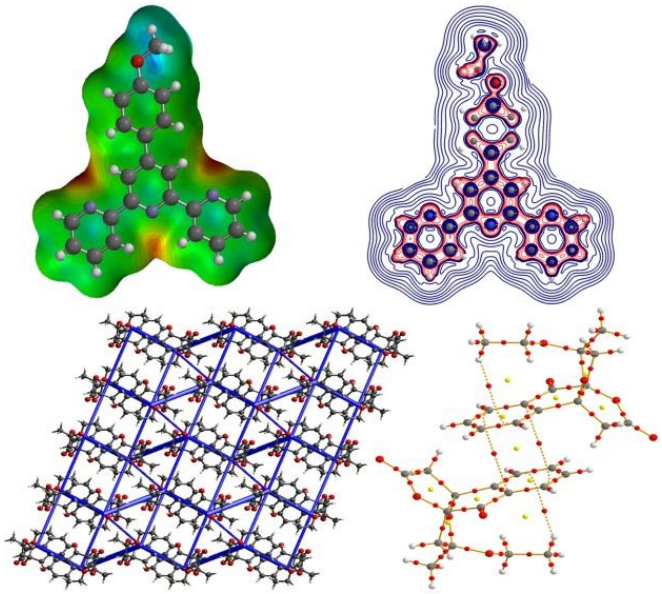


Rajni Kant,
Department of Physics, University of Jammu, Jammu.
Email: rkant.ju@gmail.com

This research group has dealt with the crystallographic aspects of a large number of medicinally important organic and inorganic materials. The main focus of his research group is (i) to grow X-ray diffraction quality single crystals, (ii) elucidate crystallographic structure by using X-ray source, (iii) computing molecular interactions and hydrogen bonding analysis and lattice energy calculations. He created an X'Calibre SCXRD as a National Facility at Jammu University under a DST-Mega project. He has worked mainly on materials like biphenyls, steroids, Coumarins, alkaloids, etc. His work on reproducible crystallization of biphenyls and its description on why chemically-similar-looking organic molecular entitites do not pack themselves easily remains a stand-alone work which he carried out under a DST sponsored project at Oxford University.

Saikat Seth,
Department of Physics, Jadavpur University, Kolkata 700032, West Bengal, India.
Email: saikatcryst@gmail.com

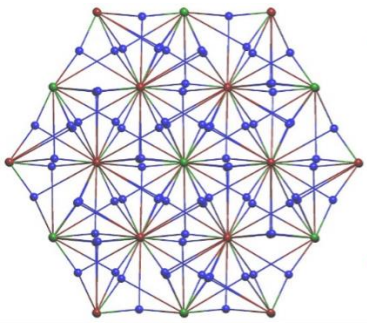
The research interests of Saikat Seth are in Chemical Crystallography, Crystal Engineering, Non-covalent interactions, Supramolecular Self-assembly, Metal-organic Frameworks (MOFs), Hirshfeld Surface Analysis, Polymorphism, Pharmaceutical Co-crystals, Quantum Mechanical Study of small molecules, Density Functional Calculations, Crystal Growth of Non-linear Optical Materials.



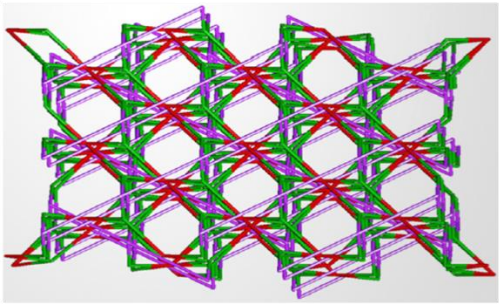
Shaikh M. Mobin,
Discipline of Chemistry and Adjunct Faculty, Disciplines of Metallurgical Engineering and Materials Science (MEMS) and Biosciences and Biomedical Engineering (BSBE), Indian Institute of Technology Indore.
Email: xray@iiti.ac.in

The research group of S. M. Mobin has evolved as a multidisciplinary research group primarily working in the development of nanomaterials and biomaterials with inorganic and organometallic precursors. Inorganic and organometallic complexes synthesized by them are employed as single source molecular precursors (SSMPs) for synthesis of novel metal / metal oxides nanoparticles. These metal / metal oxides nanoparticles prepared by SSMPs' are employed in diverse areas ranging from catalysis for organic transformations, photocatalyst and to construct solar cell device with improved

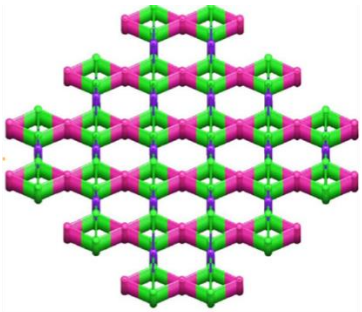
efficiency. Further, they are also involved in designing series of sensors viz. chemical sensors, biosensors and fluorescence sensors for detection of biomolecules like glucose and cholesterol, trace amounts of transition metal, heavy metals, noble metals and anion sensing. For more details visit: **http://www.iiti.ac.in/people/~xray/index.html**



3,3,12-c net, ***smm*1** topology



3,4, 8-c net, ***smm*2** topology



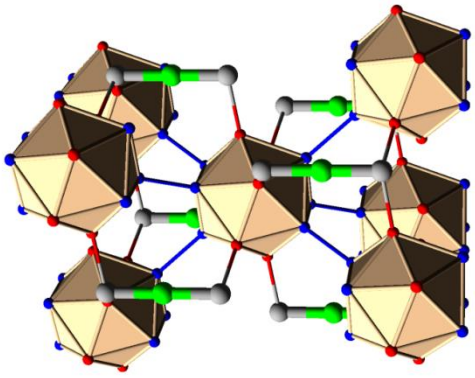
4,4, 6-c net, ***smm*3** topology

Susanta K. Nayak,
Department of Chemistry, Visvesvaraya National Institute of Technology (VNIT), Nagpur, South Ambazari Road, Maharashtra-440010, India.
Email: sknayak@chm.vnit.ac.in

He is working on organic molecules utilizing the concepts in Crystal Engineering & Supramolecular Chemistry for biological activity study and establishment of structure-property relationship. They are also involved in the development of organic and organic-inorganic hydrid (soft) materials for liquid crystalline (mesogenic) property study utilizing the non-covalent interactions along with aspects related to presence of polymorphism and co-crystals study of pharmaceutical (Drug) molecules and their physico-chemical properties. For more details visit: **http://chm.vnit.ac.in/people/sknayak/.**

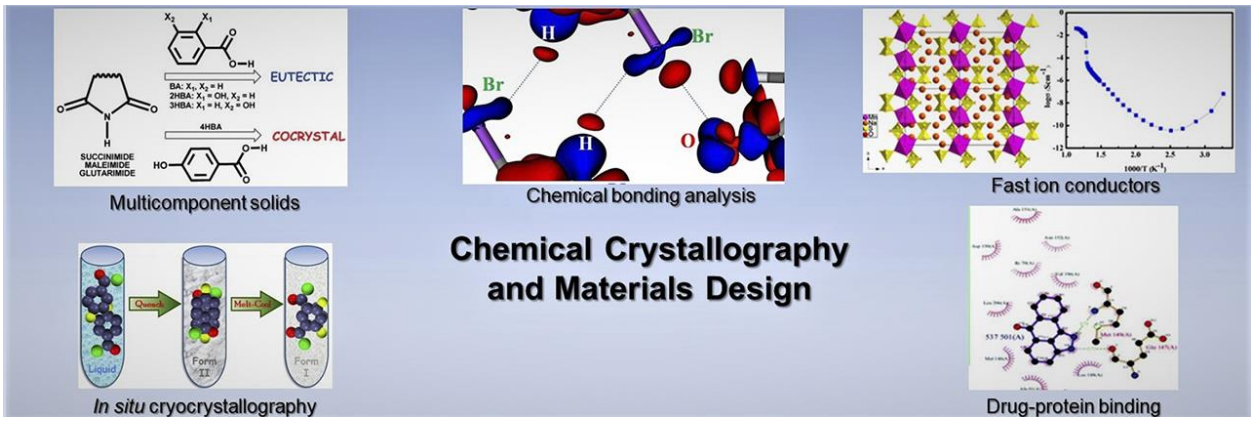
Swastik Mondal,
Functional Materials and Devices Division, CSIR-Central Glass and Ceramic Research Institute, Kolkata, India.
Email: swastik_mondal@cgcri.res.in

The primary research direction of Swastik Mondal is to analyze crystal structures, electron densities and electronic states in crystalline materials for gaining insights into the properties of materials. The research activities are aimed at applying X-ray based techniques to understand chemistry and physics of solid state materials, especially to explore steady states of electrons in materials under normal condition and under the influence of temperature, pressure and electro-magnetic fields. The specific subfields covered by Dr. Mondal includes the analysis of static and dynamic aspherical charge-density analysis, *Ab-initio* structure determination, and single-crystal structure analysis of periodic and aperiodic crystals. For more details visit: **https://www.cgcri.res.in/research/research-divisions/functional-materials-devices/dr-swastik-mondal/**



T. N. Guru Row,
SSCU, Indian Institute of Science Bangalore- 560012, India.
Email: gururow@iisc.ac.in

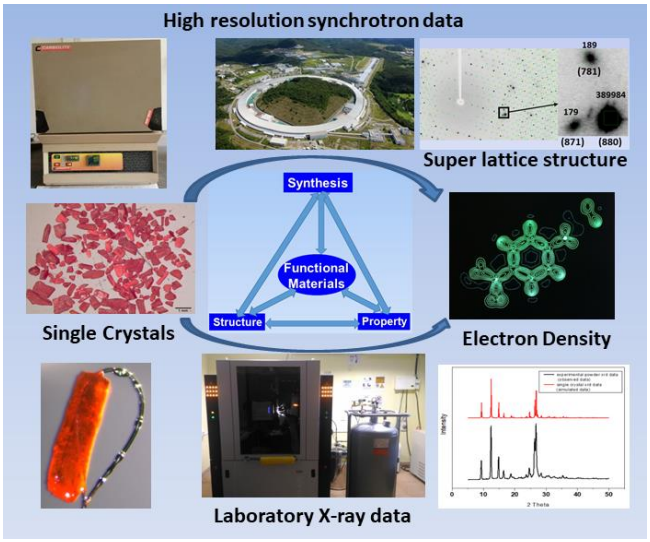
The research group of Prof T.N. Guru Row works in the area of electron density analysis from high resolution X-ray diffraction, crystal structures of complex minerals to unravel the pathways of evolution of minerals, *in situ* crystallization, phase transition in molecular crystals and design of small molecule inhibitors. For more details visit: **http://sscu.iisc.ac.in/faculty/row/**



Venkatesha R. Hathwar,
Department of Physics, Goa University, Goa.
Email: vhathwar@unigoa.ac.in

His group research activity is focused on structure-property correlation in functional materials using X-ray and neutron diffraction data. The structural studies are further supported by the electron density analysis. In this context, the broad area of target compounds is pharmaceutically active organic molecules, cocrystals, organic semiconductors, spin-crossover complexes, perovskites and 2D layered materials. Experimental electron density distributions in these compounds are determined using high-resolution X-ray data from laboratory and synchrotron sources. The experimental observations are supported/corroborated by computational methods. The electrical, magnetic and optical properties of compounds are correlated with the structural results and subtle features of electron density distribution.

For more details visit: **https://www.unigoa.ac.in/faculty/venkatesha-r-hathwar.html**



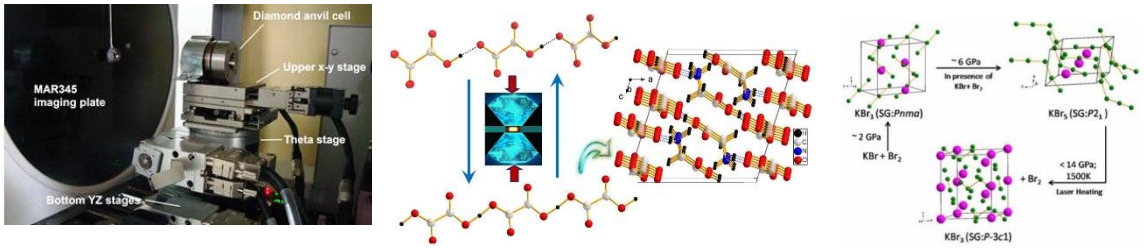
Crystallography at Bhabha Atomic Research Center (BARC, Mumbai, Maharashtra)

Neutron diffraction studies are carried out on a wide variety of multiferroics, transition metal oxide based functional materials, garnets, and layered oxides etc. These studies are aimed at understanding a variety of phenomena, for example, the importance of ionic size variance in site disorder and melting of the charge, spin, and orbital ordering, structure property correlations as a function of composition, temperature, pressure and particle size, presence of ion conduction pathways through polyhedral networks etc. Another key area of research is to understand the molecular conformation, intermolecular interactions, hydrogen bond interactions and hydrogen atom stereochemistry in hydrogen bonded systems. These include hydrates, biomolecules, electro-optic materials, etc. These studies are primarily carried out using single crystal neutron diffraction at different temperatures.

Powder and single crystal diffractometers at Dhruva reactor, BARC, Mumbai

Scientists involved: *S. M. Yusuf, Dr. P. U. Sastry, A. Das, P. S. R. Krishna, R. Chitra, Rajul Ranjan, K. R. Chakraborty, Amit Kumar, Anil Jain, S. K. Mishra, and A. K. Bera*

High Pressure and Synchrotron Radiation Physics Division (HP & SRPD) is involved in understanding the behaviour of materials under different thermodynamic conditions (variable pressure, temperature or pressure and temperature). High pressure studies help us to determine the transition pathways, understand the deep earth processes or the presence/absence of different minerals in extra-terrestrial planets. Crystal structure data at high pressure also helps to determine the equation of state (EOS), which is an important input in hydrodynamic codes used for simulations of fission and fusion devices and their effects. A dedicated group of scientists in this division, works on crystallography of different materials (geophysically relevant materials, Organic materials, Metal organic framework, perovskites, pyrochlores, topological insulators, transition metal dichalcogenides, Intermetallics etc.) at high pressures using various pressure devices. The HP & SRPD has developed an Extreme Conditions X-ray Diffraction (ECXRD) beamline at BL-11 port of Indus-2 synchrotron source. This beamline has been particularly optimized for high pressure experiments.



Experimental facility at BL-11, (b) Dynamic proton sharing in glycinium oxalate at moderate pressures (8 GPa) (c) Formation of unconventional stoichiometric compounds in K-Br system at high pressure and high temperature.

Scientists involved: *Dr. Nandini Garg, Dr. Alka B. Garg, Dr. Meenakshi Sunder, Dr. S. Karmakar, Dr. H. K. Poswal, Dr. A. K. Mishra, Dr. K. K. Pandey, Dr. N. N. Patel, Dr. B. Bhooshan, Dr. Velaga Srihari*

Research in **protein crystallography** at BARC has evolved into a multidisciplinary program. At RB & HSD, the structural studies of many macromolecular systems have been carried out using single crystal x-ray diffraction. The major focus of the group is to understand the complex biology of various life-processes at the molecular level. Besides, the focus is also on computer-aided drug discovery and protein engineering. These include HIV protease, bacterial phosphatases, eukaryotic translin-like proteins, human proteins from seminal plasma and protein kinases, mosquito-larvicidal proteins, solar energy harvesting phycobiliproteins, and the proteins involved in cellular redox responses. Many crystal structures of drug-like

compounds synthesized in this group have been determined and a chemical library has been developed to screen against various drug targets. The major targets for these studies are the proteins related to cancer and HIV/AIDS. Recently, the group has also undertaken the structure-function studies of various proteins of SARS-CoV-2. The major emphasis will be to understand the molecular biology of the virus and develop potential inhibitors against the viral targets.

Scientists involved: *Mukesh Kumar, Lata Panicker, Gagan Deep Gupta, Vishal Prashar, Amit Das, Subhash C Bihani, Bharati Pandey, Shweta Kumari, Rimanshee Arya.,*

To determine the crystal structures (using single crystal x-ray diffraction) of important macromolecules such as proteins and their complexes with different ligands, Physics group at BARC has also developed a dedicated beamline (BL-21) at INDUS-2. The macromolecular structure solutions are either obtained by molecular replacement or by single- and multi-wavelength anomalous diffraction experiments (SAD, MAD) by fine-tuning energy of the x-ray beam. The beamline can be tuned to desired energy in the range between 5 to 20 keV (with bandwidth of ~1 eV) corresponding to wavelength of 2.48– 0.62 Å. The beamline is associated with a well-equipped biochemical laboratory and cold rooms to grow, cryo-soak and cryo-freeze the protein single crystals.

Scientists involved: *Ravindra D. Makde, Biplab Ghosh, Ashwani Kumar, Rahul Singh,*

Chemistry division is involved in the synthesis of novel materials with lanthanides, actinides like uranium and thorium, ceramics materials relevant for nuclear technology as well as electro-ceramics, magnetic materials, organic and organometallic materials, pyrochlore type rare-earth zirconates and titanates; perovskite type manganates, chromates, ferrates, metastable materials like $Ce_2Zr_2O_7$, ZrU_2O_7, $CeCrO_4$, Li_3ThF_7, etc. Novel framework type phosphates, managantes, and titanates have been synthesized with the aim of selective separation or immobilization of radioactive materials. Crystallographic research in this division is focused on structure-property correlations, structure of novel materials, structural stability and usability, and evolution of crystal structure at different temperatures using powder x-ray diffraction. The compositional dependence of structure, electrical and magnetic properties of pyrochlores and pervoskites is also being investigated.

Scientists involved: *Dr. A. K. Tyagi, Dr. S. N. Achary, Dr. R.Shukla, Shri Amey P. Wadawale*