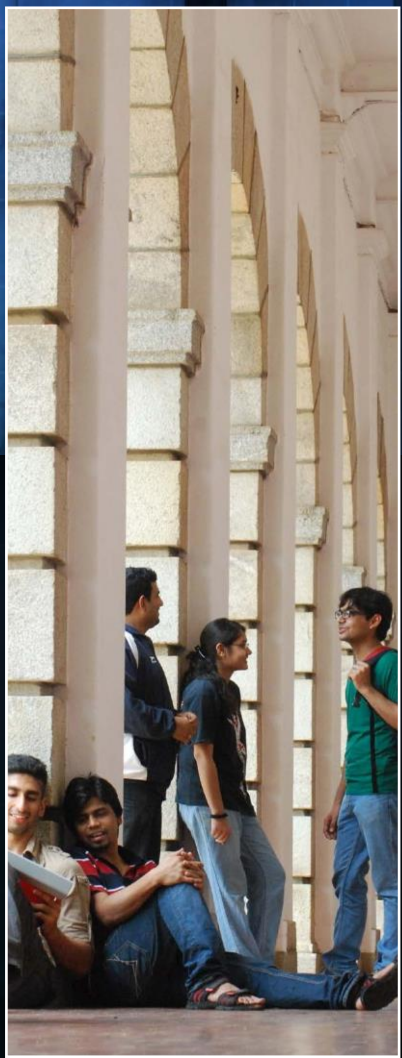
Department of
Chemical Engineering



Indian Institute of Science, Bangalore

Contents

Message from the
Chairman

On behalf of the members of our department, I extend my warm greetings to you. Situated in a century-old renowned institution, the department is over 70 years old. Through the years, it has built high quality teaching and training programmes, and has been engaged in tackling problems of current and future technological and societal importance to India. We are proud of our students who have gone on to work in a diverse range of industries and institutions all over the world.

The research conducted in the department today is truly multi-disciplinary, aimed at opening new frontiers in Chemical Engineering and enriching the existing ones by leveraging on concepts from Biology, Chemistry, and Physics at nano and larger length scales. The latest technological breakthroughs and advances in computational power are continually incorporated to facilitate simulations and new challenging experimental investigations, ranging from molecular scale to macroscales. I urge the visitor to look through the web pages hosted on this site, including those of our faculty.

Through the Outreach programme, we conduct internship programmes for college students and deliver lectures in colleges. We also extensively collaborate with scientists in other fields, medical professionals, and industry to move towards our goals.

The coming years, with rapid advances all around in many fields, and increased awareness of environmental, energy, health and society related issues pose many challenges and new opportunities for us to make significant contributions. Our department aims to remain one of the premier departments of Chemical Engineering in the country and strives to achieve a place among the best departments in the world.

Sanjeev Kumar

Origins and Evolution of the Department

The Department of Chemical Engineering was started in 1943 as a wing of the Division of Pure and Applied Chemistry at the Indian Institute of Science (IISc). The Chemical Engineering wing earned the full status of a department in 1947. In 1961, it was affiliated to the Engineering Faculty and renamed the Department of Chemical Engineering (ChemE).

Our department began as a center of excellence in research and higher education in chemical engineering to address the needs of a phenomenally growing chemical industry in post-independence India. It has evolved significantly over the last six decades, reflecting changes in the Indian chemical industry and the chemical engineering profession worldwide. Research in the fifties and sixties was focussed on thermodynamics, reaction kinetics, catalysis, and unit operations, and was followed in the seventies by chemical reactor theory and transport processes. Scores of catalysts were developed for homogeneous and heterogeneous reactions central to our industry, and a variety of chemical reactors were designed and analyzed. Gradually, the focus shifted to more basic research in multiphase systems. In subsequent years, our department went on to make major theoretical contributions in multiphase systems and won considerable national and international acclaim.

Newer areas like colloid and interfacial science, biochemical engineering, complex fluids, and polymer science appeared on the chemical engineering arena in the eighties. The department has emerged today as a center of excellence in modelling complex fluids and advanced materials. Endeavors in biochemical engineering initiated during the eighties have culminated today in the establishment of several novel bioreactors across the country.

This millennium is witnessing the fusion of traditional chemical engineering areas with modern fields like information science, communication technology, nanoscience, and biology. In keeping with this transition, our department today has acquired a significantly interdisciplinary character.

Our current activities extend to such diverse areas as biochemical and metabolic engineering, colloid and interfacial science, polymer engineering and science, complex fluids, environmental engineering, granular flows, molecular modelling and simulation, nanotechnology, theoretical biology, transfer processes, and process systems engineering. At the same time, we retain our traditional strengths as work on reactor analysis and multiphase systems, continues.

Our department has had a longstanding tradition of providing its students with chemical engineering education of the highest international standards. We currently offer programmes leading to the Masters and Doctoral degrees. The high faculty-to-students ratio facilitates close interaction and a cherished informal atmosphere. Since 1961, more than 500 degrees have been awarded in the Masters, and PhD programmes. Our alumni today include industrialists and academicians in India and abroad.

Facts at a Glance

Student body

The department is home to about 38 PhD, 8 M.Tech (Res)(Engg) and 17 M.Tech students. The students join IISc ChemE department from all parts of country after graduation from NITs, IITs and other reputed institutions. The average span of time spent by a PhD, MSc and ME candidate is 5, 2.5 and 2 years, respectively.

Faculty

Twelve full-time professors, form the core of the academic staff at the department. The faculty are well-known authorities in their fields and many are fellows of the major science and engineering academies of the country, and /or won awards recognizing their professional achievements. Two of our professors are also recipients of the prestigious Shanti Swaroop Bhatnagar award. Apart from this, several of the retired and emeritus professors still maintain a strong connection with the department.

Measures of excellence

Apart from IISc being ranked in the top 100 schools in the world (Shanghai rankings, 2013), it was ranked 8th globally in the "best small universities" category by the Times Higher Education or THE Rankings (2017). ChemE department is consistently ranked in the top 100 chemical engineering programmes in the world (QS Top university rankings, 2016). It is considered one of the top chemical engineering departments in the country for graduate studies.

Teaching and Research

The chemical engineering department strives for the highest international standards of teaching and research. Apart from seven core courses that cover engineering, mathematics and basic chemical engineering principles, as many as eleven elective courses spanning environmental engineering to theoretical biology are offered. Research in the department is a critical part of the teaching process and each of the degree programmes require thesis work ranging from one (MTech) to approximately five (PhD) years of dedicated research and training.

Publications

Our department has many prolific researchers and the average number of publications is greater than 50 per year. Several of the professors have also authored well-known graduate texts and research monographs.

Funding

The department is funded well from various government agencies such as Department of Science and Technology (DST), Department of Biotechnology (DBT), Council of Scientific and Industrial Research (CSIR) and international organizations like NIH and Wellcome Trust. The department operates several major grants like IRPHA, FIST and one center of excellence. We also have funding from industrial colloborations (Samsung, Procter & Gamble, BPCL, etc.) which support our research activities.

Alumni

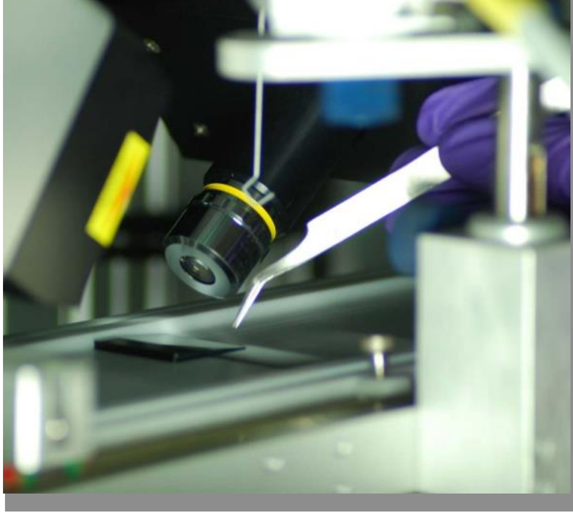
High standards of imparted training and education combined with the excellcent quality of students produces ChemE graduates from IISc who go on to lead illustratous careers. Our alums can be found in all levels of the industrial sector and occupy strategically important positions in various corporations such as Dr. Reddy's Labs, ITC and SABIC. Many of the ChemE graduates also go on to undertake successful careers in academia and can be found in top chemical engineering departments of the country.

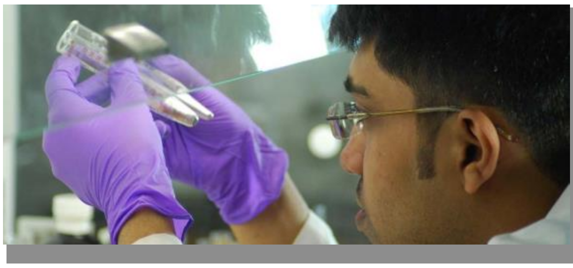
Interesting Tidbits

Here are some interesting facts and figures about our department.

- Prof R Kumar set up a fluidized bed reactor with the largest diameter of that time for roasting pyrites ore.
- Prof KS Gandhi's book on "Heat & Mass Transfer: A Transport Phenomena Approach" is highly popular among graduate students that helps them to solve transport process problems from a physical and mathematical perspective.
- Prof V Kumaran was the first to study the stability of fluid flows past soft materials at low flow speeds, an area which is becoming increasingly relevant in microfluidics and biological fluid dynamics.
- Prof G Madras has the highest number of publications and citations between 2000-2012 among all engineering faculty in India.
- Prof SK Gupta developed a new framework for discretization of population balance equations (PBEs) along with co-investigator, Dr. D Ramkrishna at Purdue which has over 500 citations.
- Prof. Manas Chanda's book on "Introduction to Polymer Science and Chemistry: A Problem Solving Approach" is followed by many Universities in India, Sweden, U.S and Canada.
- With growing environmental concerns and need for green technologies, Prof K Kesava Rao was among the few early proponents of waste water recycling from hostels and other places in the institute.
- Prof Jayant Modak was instrumental in setting up plants for the treatment of effluent water from coffee plantations and the extraction of gold from ore tailings.

Academic Programmes





Degree Programmes

Chemical engineering at the Indian Institute of Science offers several degree programmes tailored to gain various levels of training in course and research experience.

M.Tech

This is a two-year course based Masters program designed to prepare students to address complex industrial and technological problems through an advanced knowledge of various chemical engineering subjects. A bachelor's degree in chemical engineering or a related field is necessary to enter the programme. Selection is based on the score obtained in the GATE Chemical Engineering Paper. The programme consists of 32 credits of course work and 32 credits of project work. Of the course credits, 21 credits are from compulsory core courses and the remaining from electives.

M.Tech (Research)

This is a research based Masters programme designed to prepare students for advanced chemical engineering practice through research, development, production and process design. A bachelor's degree in engineering or a master's degree in sciences with mathematics as a subject at the bachelors level (at least) is required to enter the programme. Selection is based on the score obtained in the GATE exam and an interview.

Each student selects a research advisor and plans a programme of course work and thesis research. A minimum of 12 credit hours of graduate course work, of which at least 6 credits are from core courses, in addition to a 3 credit mathematics course are required for the MSc (Engg) degree. Independent research work is assessed through a general test midway into the programme and a final defense of the thesis.

Doctor of Philosophy, PhD

The PhD programme is designed to prepare each student to participate in technology development, problem solving and innovation in chemical engineering, be it in industry, research institutions and universities. Students can enter the PhD programme either with a master's or a bachelor's degree in engineering. Selection is based on the score obtained in the GATE exam and an interview.

PhD applicants with a master's degree in engineering

In the PhD programme, each student selects a research advisor and plans a programmes of course work and thesis research. Twelve credit hours of graduate course work must be completed before research may begin. Independent research work is assessed by a comprehensive examination midway in the programmes and annual assessments thereafter culminating in a defense of the thesis at the end.

PhD applicants with a bachelor's degree in engineering

Each student selects a research advisor and plans a programmes of course work and thesis research. A minimum of 24 credit hours of graduate course work are required for the bachelor entrants to the PhD programmes. Independent research work is assessed through a comprehensive examination midway in the programmes annual assessments thereafter culminating in a final defense of the thesis.

External Registration and Quality Improvement Programmes (ERP & QIP)

These programmes enable mid-career professionals to acquire a higher academic degree. The ERP candidates are typically sponsored by reputed industries and research organizations. The QIP is meant for faculty members from engineering colleges to gain a higher academic degrees. In both, selection is by an interview.

Tuition fees & Financial aid

The annual tuition fee for PhD and Master students is Rs. 9000 and Rs. 6000, respectively. The PhD students receive monthly scholarships of Rs. 25,000-28000. The Masters students receive Rs. 12,400 per month. Several other awards from IISc and government agencies like Council of Scientific and Industrial Research (CSIR) and Department of Biotechnology (DBT) as well as Bristol-Myers Squibb are available on a competitive basis.

Admissions

Admission to the ME program is in the August semester only. The applications are generally received in March every year. The admission procedure is advertised in all national daily newspapers in January/February every year including details of GATE, which is conducted in February.

Admission to the MTech (Res) and the PhD programmes is for the August semester (applications submission in March). Candidates are called for an interview on the basis of their scores in GATE or Joint CSIR-UGC National Entrance Test for JRF or UGC-NET for JRF. A GATE score is not necessary for students who have a masters degree. The final selection is based on the performance in the interview. Interviews are held in June.

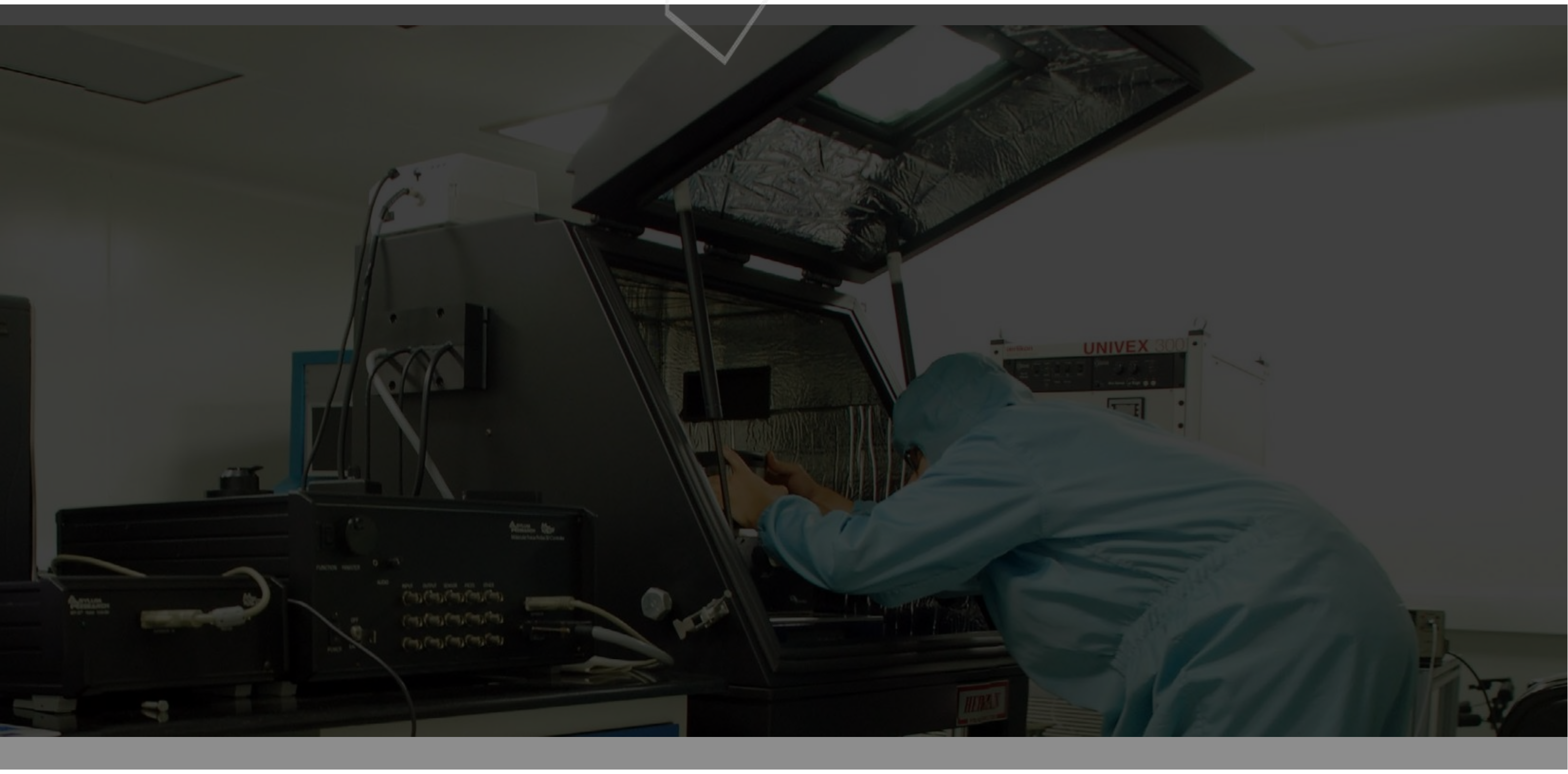
Areas of Research

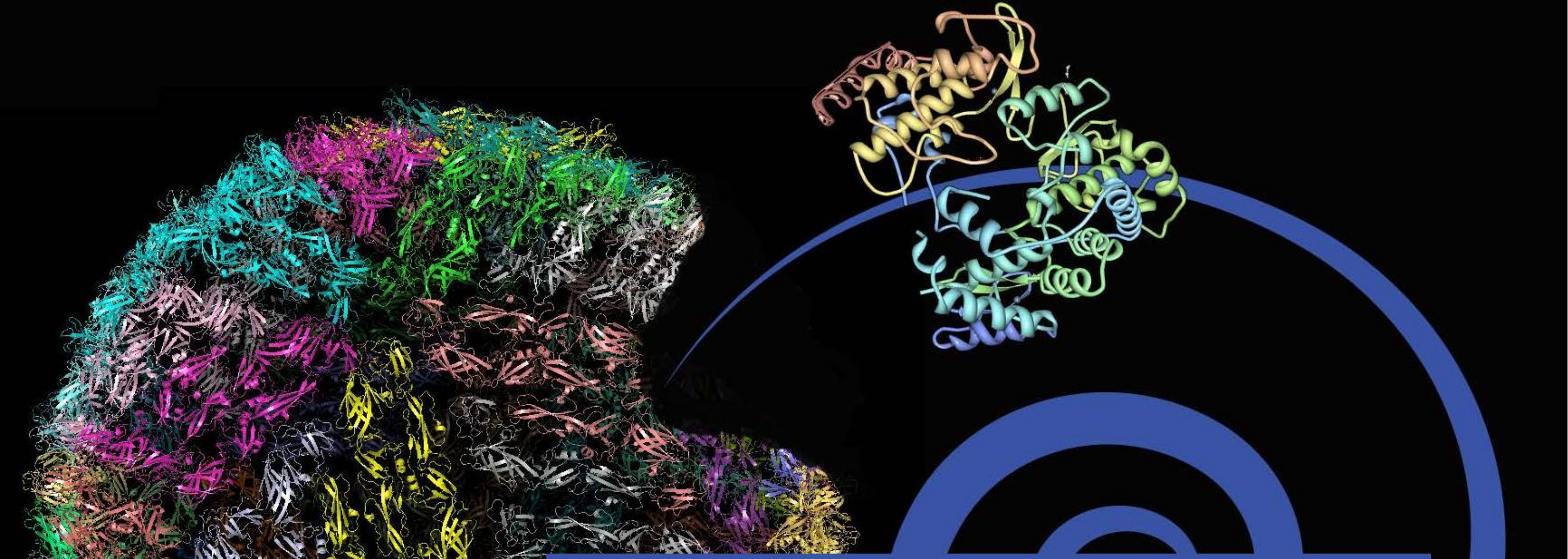
Our research areas include not only the classical topics in Chemical Engineering but also, diverse multidisciplinary areas where most recent and challenging problems are being addressed. Many unsolved problems in various disciplines require substantial knowledge of chemical engineering. Combined with our rigourous coursework students are motivated to learn many new topics and thereby enhance their problem solving skills from a scientific and engineering perspective.

Our research areas include:

- Biomolecular Engineering
- Catalysis and Reaction Kinetics
- Colloids and Interfacial Science
- Complex Fluids
- Energy Engineering
- Environmental Engineering
- Nanotechnology
- Thermodynamics, Statistical Mechanics and Molecular Simulations

Faculty	Thermodynamics, Statistical Mechanics and Molecular Computations	Nanotechnology	Environmental Engineering	Energy Engineering	Complex Fluids and Transport Processes	Colloids and Interface Science	Catalysis and Reaction Engineering	Biomolecular Engineering	Microfluidics
KG Ayappa	●					●		●	
NM Dixit	●						●	●	
SK Gupta		●		●		●			●
V Kumaran	●				●				●
G Madras		●	●	●		●	●	●	
JM Modak							●	●	
PR Nott					●	●		●	●
KK Rao			●				●		
R Roy		●						●	●
P Sudeep	●	●		●		●			
B Toley									●
S Venugopal		●		●		●			





Biomolecular Engineering

Engineering of biological processes from the molecular to the organismal scale is central to addressing key problems in medicine and healthcare as well as energy and environmental sustainability. Our department employs a unique blend of theory, simulations, and experimental techniques for biomolecular engineering. Fully atomistic and coarse grained molecular simulations are being developed to derive fundamental insights into protein interactions underlying disease states, which help identify novel drug and vaccine targets. Sophisticated single molecule spectroscopic experiments have been set up to probe rare molecular interactions within living cells, allowing first-hand observations of events that cause development and disease. Viral infections that are important globally and nationally, such as HIV, hepatitis C, and dengue, are an important focus of our efforts. Modelling and simulations of viral dynamics and evolution coupled with single molecule experiments and data from patients, obtained in collaboration with clinicians, are being employed to unravel the origins of the failure of current treatments and to design more potent and economical therapeutic protocols. Reaction network theory and experiments on quorum-sensing are being used to understand cellular signalling events and emergent systems-level properties that viruses and bacteria manipulate to overcome our immune response, presenting new avenues for vaccine design. Metabolic engineering of bacteria coupled with optimization and control techniques for bioreactors is being exploited to produce biofuels and degrade environmentally harmful effluents and waste. Our efforts thus synergize a broad spectrum of engineering and design techniques to achieve precise manipulation of biological phenomena for improved healthcare and sustainable development.

Catalysis and Reaction Engineering

Developing new catalysts, methods, and processes that deliver efficient and economical ways to carry out chemical transformations encompasses this field. Using knowledge from catalytic chemistry, reaction mechanisms, reaction kinetics, and transport processes, researchers in the department are trying to improve on reactions that span from polymer degradation to biomass conversion in reactors. Significant progress has been made in understanding of polymer polymerization and degradation under various conditions using experimental and kinetic modelling. Other interesting avenues of pursuit are in the development of catalysts for organi cs degradation and enzymatic catalysis in supercritical carbon dioxide. Similarly, designing and engineering improved steps for nanoparticle synthesis are allowing us to develop new reactors/contactors to control nanoparticle mean size and polydispersity. Efforts are also ongoing to unravel systems level properties of complex cell signalling and transcription networks applying ideas from reaction network theory, with the goal of identifying novel drug targets and outcomes of intervention. Another key theme has been to understand the mineral-microbe interactions that can be utilized for bioprocessing of various industrial materials. Using detailed mathematical models for coupling multiphase transport phenomena and biochemical reaction kinetics in bioreactors, problems in bioleaching of minerals and ores, biological adsorption of toxic metals and biomethanation of biomass are being addressed.

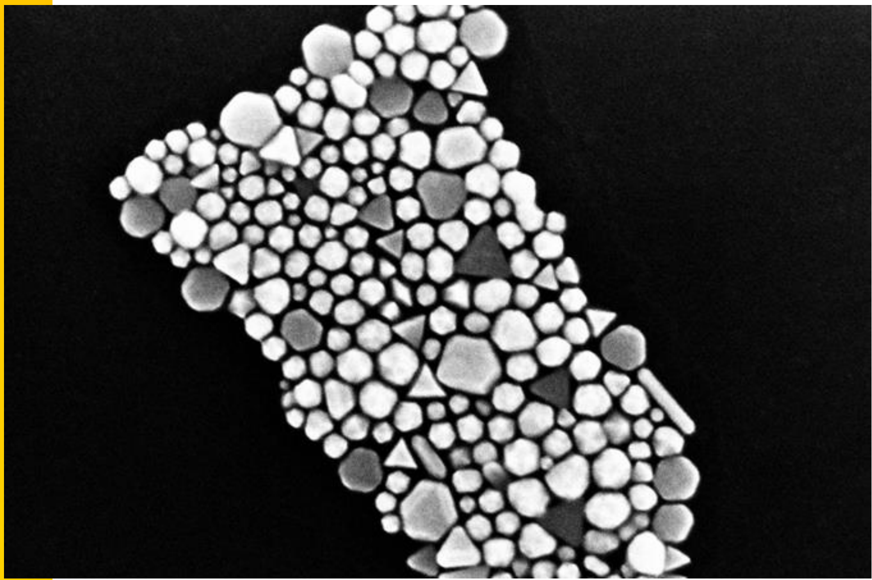
Colloids and Interface Science

A reduction in the length scale of reactors and attempts to create microstructured systems with novel and desired properties have brought in the interplay of colloidal and interfacial interactions to prominence over a broad range of length scales. Our department has earlier contributed richly to the understanding of bubble and drop formation at orifices, foam bed contactors/ reactors, and agitated dispersions.

Researchers are currently engaged in investigating colloidal interfacial behaviour at nano and sub-nano length scales. Synthesis of nanoparticles, nanowires, and nanorods, and formation of arrays and superlattices of nanoparticles for a variety of applications are controlled by manipulation of colloidal interactions and nucleation of a new phase. The formation of monolayers and bilayers and modulation of their properties for lubrication and oral care applications through sub-nanoscale chemical substitutions is another focus area in the department. Current research efforts in the department to store electrical energy efficiently in classical and novel batteries and super-capacitors draw heavily from new materials and interaction entities such as ions, charged surfaces, charged cavities, and charged micro-porous solids. These new storage systems are required to harness power from solar and other renewable resources.

Complex Fluids and Transport Processes

From food grains and processed foods, through industrial products such as paints and mineral slurries, to hygeine and cosmetic products such as toothpaste and lotions, complex fluids are an intimate part of our lives. They range from multi-phase mixtures (e.g., ice-cream, a dispersion of fat globules, ice crystals and air bubbles in an aqueous liquid) to simply a collection of discrete particles (e.g. dry food grains). They are interesting subjects for study because their response to applied forces is more complex than that of "normal" fluids such as water and air. Though diverse in their constitution, there are similarities in important aspects of their behaviour, and also in the tools used for their study. Faculty in our department engaged in studying complex fluids employ a variety of tools: experimentation at macroscopic and microscopic scales, continuum mechanical modelling and computation, and particle-dynamics simulations. We have groups engaged in the study of granular flows, fluidized beds, solid-liquid and liquid-liquid dispersions, and liquid-crystalline mesophases, to name a few. Our tools of experimentation include rheometry, high-speed imaging, confocal microscopy, and the use of soft microchannels for synthesis and mixing of fluids. Our computational tools span length and time scales from study of phenomena at the molecular scale, through mesoscale dynamics and population balances, to continuum mechanical simulations. Through our studies, we hope to achieve two objectives. On one hand, we want to develop materials and design processes required for today's technology and on another, we hope to understand the fundamental physical and chemical processes that underly the dynamics of complex fluids, which in turn will help in the design of newer and novel products and processes of the future.



Nanotechnology

Buoyed by the ever-advancing ability to characterize, control and fabricate materials at the nanoscale, the interdisciplinary field of nanotechnology is becoming pervasive in every aspect of our lives. The potential application areas of nanotechnology range from semiconductor electronics, smart materials, energy solutions to biological diagnostics. Nanotechnology research in our department similarly ranges in its diversity and extends from simulations to understand phenomenon at the nanoscale to the engineering processes for generating nanomaterials and nanoarchitecture.

Researchers are applying molecular dynamics and Monte Carlo simulations to understand structure and dynamics of fluids confined to the nanoscale that are important for developing novel gas storage applications and enhancing our molecular view of wear at the nanoscale. Similarly, population balances approaches are being employed to investigate the role of various mechanisms, such as nucleation, growth, coagulation, capping, and ripening of nanoparticles in influencing particle size distribution to develop better and efficient nanoparticle synthesis methods. Aggregation and 3D nanoparticle array formation is being modeled with thermodynamic and statistical mechanics approaches.

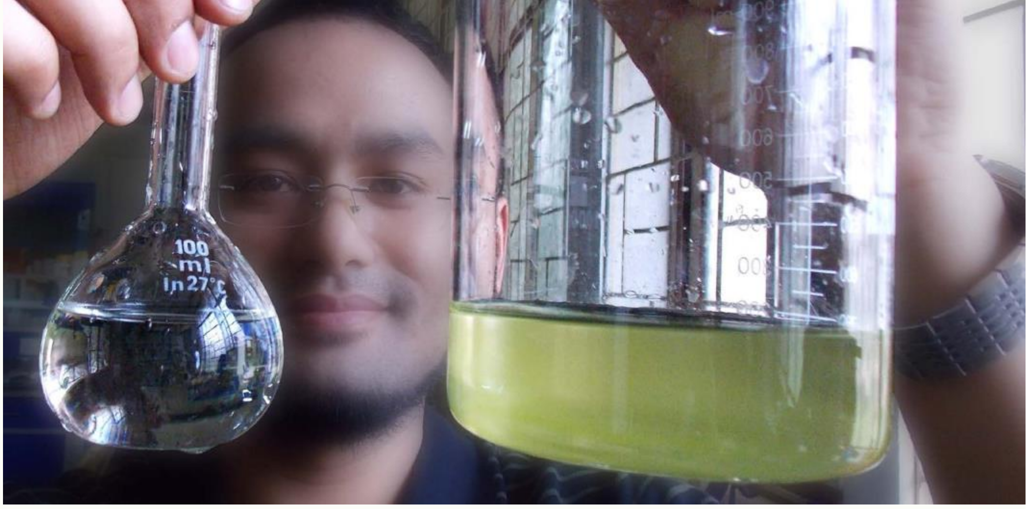
Novel technologies are being pioneered for high throughput synthesis of metal nanoparticles and semiconductor nanowires in large scales. Extending these for generation of functional nanoscale architectures with guided self-assembly to form 2D and 3D superlattices is a key theme of the current work in the department. Researchers in our department are also interested in biological processes at the molecular level to understand underlying mechanisms. Design and characterization of polymers at the nanoscale has led to the development of new materials with unique structure, properties, and functions.

Energy Science and Engineering

The standard of living across the nations is strongly correlated with per capita energy production. Given the limited and finite nature of fossil fuels and the problems associated with the traditional renewable resource such as hydel power, it is imperative to develop technologies to harness and store energy from renewable sources such as solar energy, wind energy, tidal energy, etc. Renewable energy also has an additional advantage of being by and large environment friendly.

In this department, pioneering research is being carried out towards the development of new materials and processes for energy capture and storage. Fundamental work on methane and natural gas storage using novel adsorbents such as metal organic frameworks (MOFs) and covalent organic frameworks (COFs) is currently pursueds using computational tools such as ab-initio electronic structure calculations and classical Monte Carlo simulations. Continuum and molecular modelling studies pursued in the department are helping us in improving the design and performance of rechargeable batteries and super-capacitors. Fundamental work on nanoparticle self-assembly carried out in the department is helping towards development of novel devices that greatly enhance the collection efficiency of solar power.

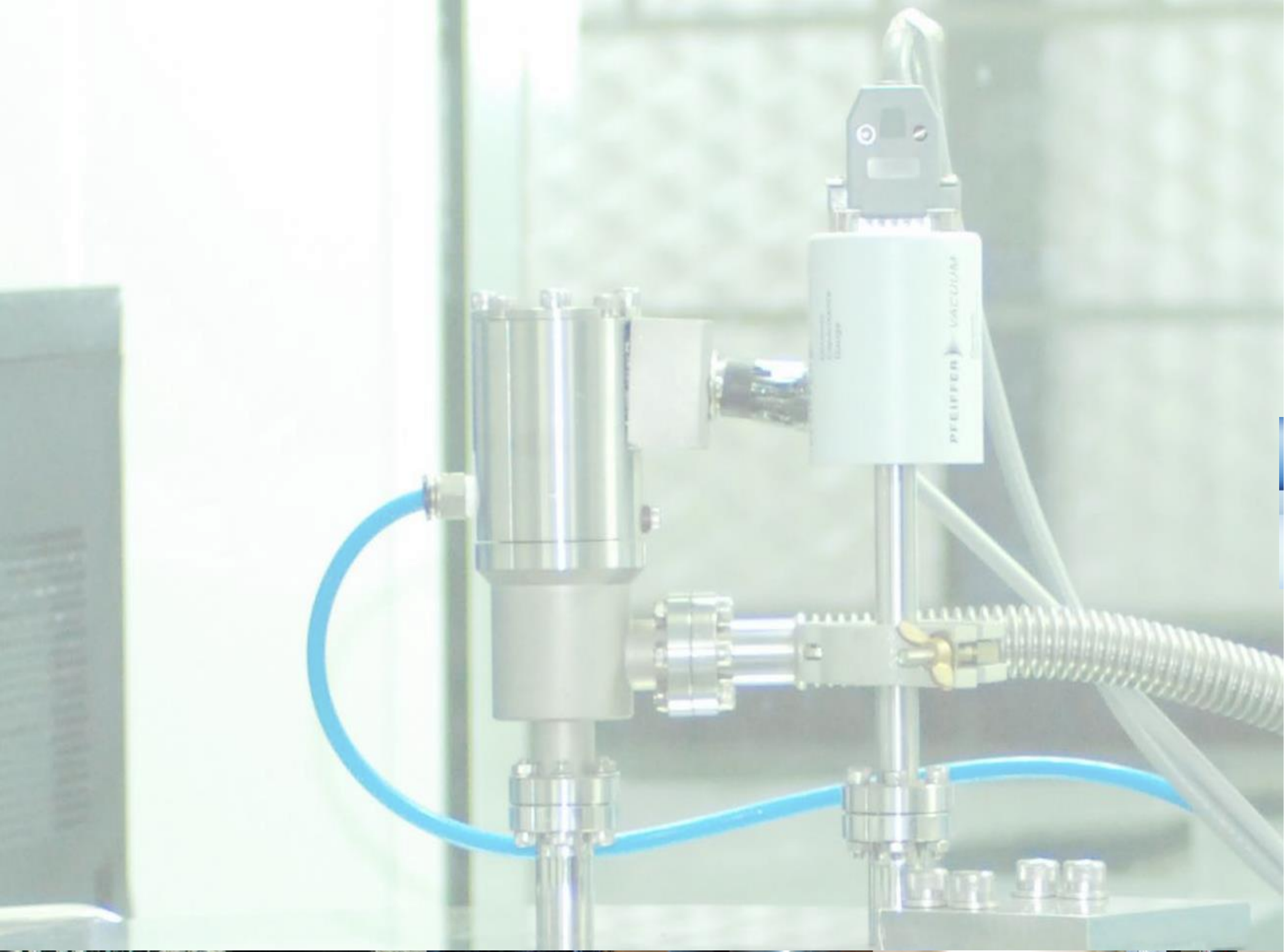
Environmental Engineering

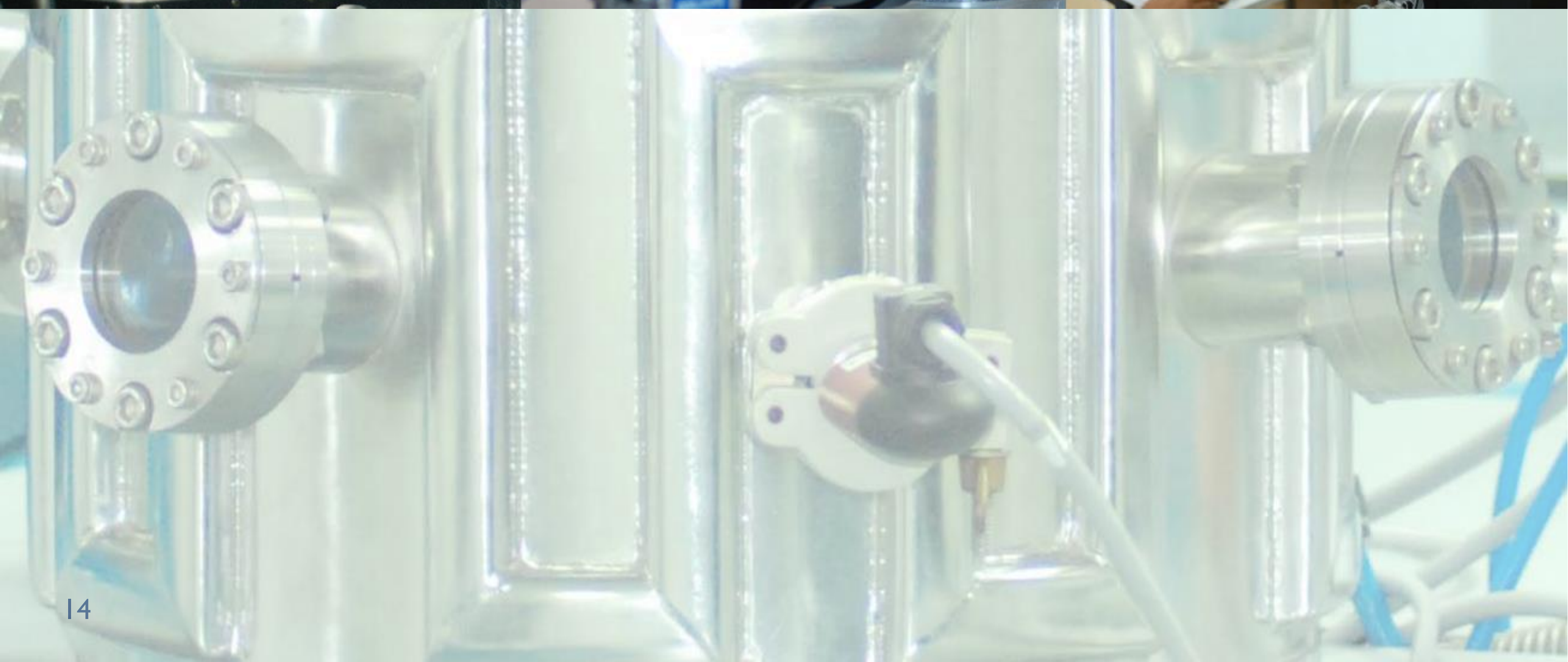


Research work in our department addresses problems of land, water, and air pollution. Consider the problem of plastic waste that is plaguing many of our cities and towns. We are trying to degrade the polymers in solution, using a variety of techniques. Even though the projects have not covered the last mile between lab and the land, we hope to do so within the next few years. Several promising photocatalysts have been developed that appear to be good at degrading pollutants in waste water from industries. Similarly, supercritical solvents have been developed for enzymatic reactions to produce compounds that are used in the pharmaceutical and food industries. Efforts has also been focused to develop activated carbon fabric and modified granular activated carbon for the removal of gases such as CO_2, NOx, CO and also Cr and As. Work is in progress to reduce or eliminate foul smell from the sites (landfills) that have been identified by the Corporation of Bangalore. Methods have been developed to determine sub-microgram levels of Mo and Fe in industrial effluents.
Our major research interests concern engineering and designing of processes and tools for treatment of water from various sources to make them compatible for human consumption or environmental release. One main theme has been defluoridation of drinking water where we have shown how column design and choice of adsorbents are critical to the output water quality. Similarly, we have demonstrated the use a solar still for the treatment of drinking water, rainwater harvesting and efficient disposal of spent analytical reagent can be achieved at the laboratory scale. Similar efforts are being pursued for reuse of greywater and development of inexpensive 'biosand' filters for the rural population.

Thermodynamics, Statistical Mechanics and Molecular Simulations

Understanding phenomenan at the molecular scale allows one to tailor products using a bottom-up approach. We study a wide variety of phenomenon using classical molecular dynamics and Monte Carlo simulations and statistical thermodyamics, which require a knowledge of the forces between the various molecules. This approach provides a molecular understanding of adsorption and separations processes, catalysis, energy storage for transportation, novel drug synthesis protocols, nanoparticle engineering, biomembrane function and transport in complex fluids. Using a variety of molecular simulation techniques, we study transport and phase equilibria of fluids confined to the nanoscale, fluids adsorbed in microporous materials such as zeolites and metal organic frameworks, gas hydrates, structure, dynamics and flows of complex oil-water-surfactant systems and protein biomembrane interactions. With enhanced computing power, molecular simulations are increasingly providing a powerful in silico method to predict properties of a wide variety of engineering systems without resorting to detailed experimentation. Multiscale modelling strategies which bridge molecular level information with continuum transport models that are of direct engineering relevance are also being pursued.


PFEIFFER VACUUM



K Ganapathy Ayappa

Professor

PhD, University of Minnesota

Research:

Interfaces play an important role in science and technology occurring in solid-liquid, solid-gas as well as more complex systems encountered in surfactant mesophases and biomolecular systems. Research in our group is focused on primarily understanding molecular and physicochemical properties of these interfaces. We use modeling techniques ranging from ab initio methods to study interactions at the electronic scale, molecular modeling to study the atomistic and mesoscale, as well as continuum models to study heat and mass transport. When a fluid is confined to nanometer dimensions or restricted due to the presence of a surface, the structure and dynamics of the fluid are considerably altered. We are interested in understanding the heterogeneous state of this interfacial fluid; solid, liquid or glass. This has implications while developing nanofluidic devices for transport as well as in unraveling forces between surfaces, with implications in understanding friction and lubrication. Fluids confined in microporous materials are important in the area of hydrogen or methane gas storage for transportation and carbon-dioxide capture. Here we use Monte Carlo simulations to assess a wide variety of materials such as zeolites, metal organic frameworks (MOFs) and porous carbons to study their potential as storage materials.

Biological membranes which are a critical component of all living systems is yet another example of a dynamic soft interface. Using a combination of theoretical, simulation and experimental methods, research in this area is focused on understanding the interactions of pore forming toxins and nanoparticles on supported bilayer membrane platforms and living cells. The precise mechanism for pore formation and ensuing effects on the membrane mechanical properties or mechanical stability of cells that undergo lysis is poorly understood. The interactions of proteins and nanoparticles with bilayer membranes have implications in developing novel drug and gene therapies. In collaboration with faculty in biology and physics we study the effects of protein mutagenesis and dynamics of membrane-protein interactions on supported bilayer platforms using high resolution optical microscopy techniques.

Awards:

Fellow of Indian National Academy of Engineering , 2013

Courses:

CH 201 Chemical Engineering Mathematics

CH 236 Statistical Thermodynamics

CH 247 Introduction to Molecular Stimulations

BE 202 Thermodynamics and Transport in Biological Systems

Selected Publications:

1. Assessing the Structure and Stability of Transmembrane Oligomeric Intermediates of an α-Helical Toxin, Rajat Desikan, Prabal K. Maiti, K. G. Ayappa, Langmuir, DOI:10.1021/acs.langmuir.7b02277 (2017)
2. Complex Dynamics at the nanoscale in Simple Biomembranes, Nirod Kumar Sarangi, K. G. Ayappa, Jaydeep K. Basu, Scientific Reports, 7, DOI:10.1038/s41598-017-11068-5 (2017)
3. Glassy Dynamics of Octamethylcyclotetrasiloxane Confined between Mica Surfaces: A Molecular Dyamics Study, V. Vadhana and K. G. Ayappa, Journal of Physical Chemistry B, 120, 2951-2967 (2016).
4. pH Controlled Gating of Toxic Protein Pores by Dendrimers, T. Mandal, Subbarao Kanchi, K. G. Ayappa, P.K. Maiti, Nanoscale, 8, 13045-13058 (2016).
5. Super-resolution Stimulated Emission Depletion-Fluorescence Correlation Spectroscopy Reveals Nanoscale Membrane Reorganization Induced by Pore-Forming Proteins, N. K. Sarangi, K.G. Ayappa, S.S. Visweswariah, J.K. Basu, Langmuir 32 9649-9657 (2016)

Ph: +91 80 2293 2769 Fax: +91 80 2360-8121
ayappa@iisc.ac.in

Narendra M Dixit

Professor

PhD, University of Illinois, Urbana-Champaign

Awards:

Young Scientist Medal, Indian National Science Academy, 2010

Associate, Indian Academy of Sciences, 2008-2011

Courses:

CH242 Special Topics in Theoretical Biology

BE 202 Thermodynamics and Transport in Biological Systems

Selected Publications:

1. Padmanabhan P, Dixit NM. Inhibitors of hepatitis C virus entry may be potent ingredients of optimal drug combinations. Proc Natl Acad Sci USA 2017; 114:E4524-E4526.
2. Shet A, Nagaraja P, Dixit NM. Viral decay dynamics and mathematical modeling of treatment response: Evidence of lower in vivo fitness of HIV-1 subtype C. J Acq Immun Def Synd 2016; 73:245-251.
3. Nagaraja P, Alexander HK, Bonhoeffer S, Dixit NM. Influence of recombination on acquisition and reversion of immune escape and compensatory mutations in HIV-1. Epidemics 2016; 14: 11–25.
4. Gupta V, Dixit NM. Scaling law characterizing the dynamics of the transition of HIV-1 to error catastrophe. Phys Biol 2015; 12:054001.
5. Padmanabhan P, Garaigorta U, Dixit NM. Emergent properties of the interferon signaling network may underlie the success of hepatitis C treatment. Nat Commun 2014; 5:3872.

Research:

Our research focuses on the development of mathematical and computational models of biological phenomena with the goal of improving our ability to combat infectious diseases. Our current focus is on HIV and hepatitis C. These viral infections affect hundreds of millions worldwide. Current treatments often fail and no vaccines exist. The goal of our research is to identify ways of improving the outcomes of current therapies and to devise strategies for the design of new, more potent therapies and vaccines.

The remarkable evolvability of these viruses makes the design of robust drugs and vaccines a challenge. Our recent efforts have been to develop quantitative descriptions of viral evolution using mathematical models and sophisticated computer simulations in order to identify the nature of drugs and vaccines that might exhibit lasting antiviral activity. In collaboration with colleagues in the science departments on campus, we are in the process of optimizing the design of such molecules. A second limitation of current therapies is their severe side effects. Using tools from pharmacokinetics and viral dynamics, we are developing dosing strategies that strike a balance between the antiviral and toxic effects of drugs, potentially enabling personalized medicine and minimizing costs and treatment duration.

At a more fundamental level, our research is focused on understanding how viruses evade our immune system. Our immune responses are orchestrated at multiple levels of hierarchy. Following pathogen recognition, a large series of signaling events suppresses viral replication within infected cells. Subsequently, other arms of our immune system are recruited to eliminate infected cells and viral particles. The immune response also evolves in response to viral evolution. Yet, viruses, using a handful of genes, overcome this remarkable immune machinery. We employ ideas from reaction network theory to understand these virus-host interactions and identify ways to tilt the balance in favor of the host. The resulting insights would lead to guidelines for vaccine design.

Ph: +91 80 2293 2768

narendra@iisc.ac.in

Sanjeev Kumar Gupta

Professor and Chairman
PhD, Indian Institute of Science

Research:

Our interests span diverse fields in colloidal science and interfacial engineering, ranging from nanoparticle synthesis, microfluidics, turbulent dispersions, foams, process intensification, and energy storage systems. We combine experiments, process modelling, CFD, and the framework of population balances to address problems in these areas. Discrete simulations of small systems and solution technique for population balance equations are other allied interests.

In nanoparticle synthesis, the effort in our group is focussed on developing engineering scale processes for synthesis of metal and inorganic nanoparticles. The route taken is to explore the interplay of nucleation, growth, coagulation, capping, and ripening of nanoparticles in influencing particle size distribution, and ways to externally modulate them to exercise the desired control on mean size and polydispersity. We have unravelled new pathways for nanoparticle synthesis and developed new contactors/reactors outside microfluidics framework for higher throughputs.

Our group has contributed significantly to the understanding of turbulent liquid-liquid dispersion processes, and continues to invest effort in understanding an interesting phenomenon, named phase inversion. At a critical value of dispersed phase fraction, the dispersed phase becomes the continuous phase and vice-versa. We find that the turbulent energy which controls breakup and coalescenec of drops individually has no influence on the critical value and the inversion process goes through an interesting dynamic structure close to the inversion point.

We have a strong interest in energy storage especially in batteries and ultra-capacitors. Our group has recently initiated detailed modelling and experimental efforts to understand and quantify processes at micro level, with the aim to harness the potential of flow batteries and super-capacitors. We use full scale simulations using high performance computing (224 cores XEON E5-2670 cluster) to assist us in our efforts.

We seek to join hands with others to address challenging problems around us: design of small residential buildings for extreme summer and cold in northern parts of India, energy efficient ways to recycle plastic waste in our cities, and hand operated emulsification device.

Ph: +91 80 2293 3110
sanjeevkumar@iisc.ac.in

Awards:

Indian National Science Academy Young Scientist Medal, 1998

Associate, Indian Academy of Science, Bangalore, 1997

P S Narayana Medal, Best Thesis in Mechanical Sciences, IISc, 1993

N R Kuloor Medal, IISc, 1989, 1993

Courses:

CH 233 Interfacial and Colloidal Phenomena

CH 235 Modelling in Chemical Engineering

CH 245 Computational Transport Phenomena

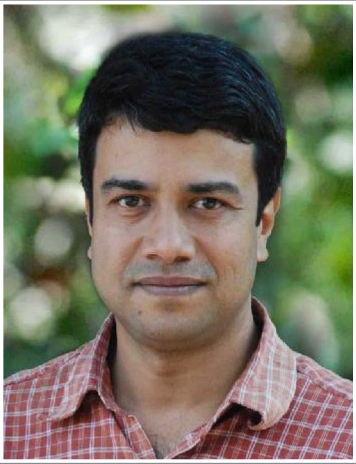
Selected Publications:

1. Siva Rama Krishana Perala and Sanjeev Kumar, On the Mechanism of Metal Nanoparticle Synthesis in the Brust--Schiffrin Method, Langmuir, 45, 203--211 (2013).
2. Kara Zabetakis, William E Ghann, S Kumar, and Marie-Christine Daniel, Effect of high gold salt concentrations on the size and polydispersity of gold nanoparticles prepared by an extended Turkevich–Frens method. Gold Bull. 45, 203-211 (2012).
3 M Girish, S Lakshmanan, KN Sravan, S Venugopal and S Kumar, Effect of Reagent Addition Rate and Temperature on Synthesis of Gold Nanoparticles in Microemulsion Route. Ind. Eng. Chem. Res. 50, 8786-8791 (2011).
4. SS Chauhan, J Chakraborty, and S Kumar, On the solution and applicability of bivariate population balance equations for mixing in particle phase. Chem. Eng. Sci. 65, 3914-3927 (2010).
5. R Reddy, and S Kumar, Dispersal of sticky particles. Europhys. Lett. 80, 56001 (2007).

V Kumaran

Professor

PhD, Cornell University



Awards:

Prof. Rustum Choksi award for excellence in research for engineering, 2012

JC Bose National Fellowship, 2007

Fellow, Indian National Academy of Engineering, 2006

Swarnajayanti Fellowship, Government of India, 2002

Fellow, Indian National Science Academy, 2001

Bhatnagar Award, Government of India, 2000

Amar Dye-Chem Award, Indian Institute of Chemical Engineers, 1999

Fellow, Indian Academy of Sciences, 1998

Indian National Academy of Engineering Young Engineer Award, 1997

Indian National Science Academy Young Scientist Medal, 1996

Courses:

CH 203 Transport Processes

CH 232 Physics of Fluids

Selected Publications:

1. S. Srinivas and V. Kumaran, Transitions to different types of turbulence in a soft-walled channel, J. Fluid Mech., 822, 267-306, 2017.
2. S.S. J. Jaju and V. Kumaran, System size dependence of the structure and rheology in a sheared lamellar liquid crystalline medium, J. Chem. Phys., 145, 244901, 2016.
3. V. Kumaran and P. Bandaru, Ultra-fast microfluidic mixing by soft-wall turbulence, Chem. Eng. Sci., 149, 156-168, 2016.
4. V. Kumaran, Kinetic Theory for sheared granular flow, Comptes Rendus Physique, 16, 51-61, 2015.
5. V. Kumaran and S. Pradhan, The generalised Onsager model for a binary gas mixture, J. Fluid Mech., 753, 307-359, 2014

Research:

In the broad areas of complex fluids and complex flows, our research interests range from molecular studies (below figure) to macroscopic applications such as microfluidic devices and fuel cells. We employ rigorous theoretical analysis (theorems in non-equilibrium statistical mechanics, kinetic theory, and hydrodynamic stability), complex simulations (rarefied gas flows, lamellar mesophase simulations from molecular to continuum scales, and large scale turbulent particle-gas simulations) and sophisticated experiments (microfluidics, and nano-engineering of catalyst layers) to uncover fundamental phenomena and to demonstrate their potential impact on applications in microreactors, hypersonic transport and energy conversion systems.

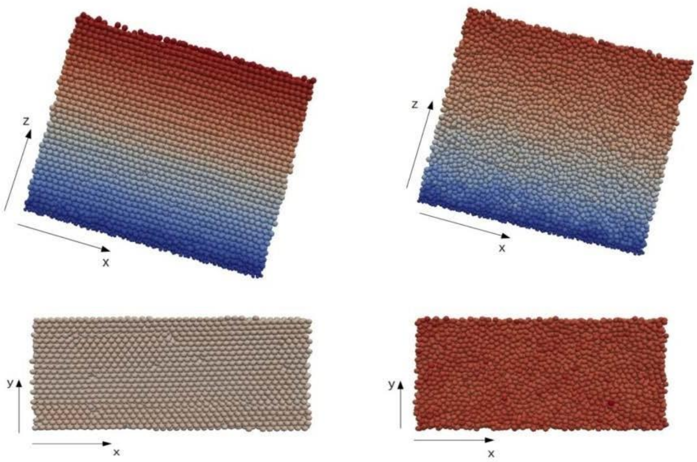


Figure shows a simulation of how granular flow behaviour changes on an inclined plane with respect to particle size ratios. Side view (top) and to view (bottom) of the flow for a ratio of base particle/ flowing particle size 0.61 (a) and 0.62 (b) at an angle of inclination = 21° is shown.

Ph: +91 80 2293 3112

kumaran@iisc.ac.in

Jayant M Modak

Professor

PhD, Purdue University

Awards:

Fellow, Indian National Academy of Engineering, 2004

Sir C. V. Raman Young Scientist Award, Government of Karnataka, 2004

Biotechnology Process Development Award, Department of Biotechnology, Government of India, 2003

Alexander von Humboldt Research Fellowship, Alexander von Humboldt Foundation, Germany, 1999-2000

Amar Dye Chem award for Excellence in Research, Indian Institute of Chemical Engineers, 1996

P.C. Ray Award, Indian Institute of Chemical Engineers, 1983

G. P. Kane Gold Medal, University of Bombay, 1983

Courses:

CH 246 Advanced Process Control

UG302 Design Principles for Environmental Engineering

Selected Publications:

1. S Sontakke, C Mohan, JM Modak, G Madras, Visible light photocatalytic inactivation of Escherichia coli with combustion synthesized TiO_2, Chemical Engineering Journal, 189, 101-107 (2012).
2. S Samira, P Akash Raja, C Mohan, JM Modak, Photocatalytic Degradation of Crystal Violet (CI Basic Violet 3) on Nano TiO_2 Containing Anatase and Rutile Phases (3:1), Journal of Thermodynamics & Catalysis, 3: 117 (2012).
3. AR Mandli and JM Modak, Evolutionary Algorithm for the Determination of Optimal Mode of Bioreactor Operation, Industrial & Engineering Chemistry Research 51 (4), 1796-1808 (2011).
4. DN Priya, JM Modak, P Trebše, R Žabar, AM Raichur, Photocatalytic degradation of dimethoate using LbL fabricated TiO_2/polymer hybrid films, Journal of hazardous materials 195, 214-222 (2011).
5. S Sontakke, J Modak, G Madras, Effect of inorganic ions, H_2O_2 and pH on the photocatalytic inactivation of Escherichia coli with silver impregnated combustion synthesized TiO_2 catalyst, Applied Catalysis B: Environmental 106 (3), 453-459 (2011).

Research:

Modelling, Optimization and Control of Bioreactors

Genomic revolution in recent decade has resulted in availability of molecular level information about functioning of the cell. Our research focuses on utilization of such data for quantitative analysis of growth and metabolite production by microbial systems. In recent years, our work is focused on methylotrophic yeast, *Pichia Pastoris*, an industrially important recombinant protein expression system. We have investigated the secretion of number of growth hormones and developed a modelling framework suitable for engineering analysis of such systems. Microorganisms are often thought of as ultimate optimal machines and our research attempts to understand the growth behavior of microorganisms using the principles and tools of control theory.

Optimal design and control of fermentation processes is a challenging and dynamic control problem. Our research in this area focuses on developing computationally efficient algorithms, which combine the rigor of optimal control theory and advanced search techniques such as genetic algorithms. Our interest is to address optimal control problems, which are characterized by their multiple performance measures, such as, yield and productivity of the bioreactor. These measures are often non-commensurable and competing with each other.

Computation Fluid Dynamics has emerged as an important tool for understanding of mass-energy-momentum interactions in multiphase reactors. One of the research area of interest to us is extending the application of CFD to enhancing the understanding of biotic-abiotic interactions in bioreactors. We are investigating several systems such as anaerobic wastewater treatment processes and photo-bioreactors for algal growth.

Advanced Waste Water Treatment

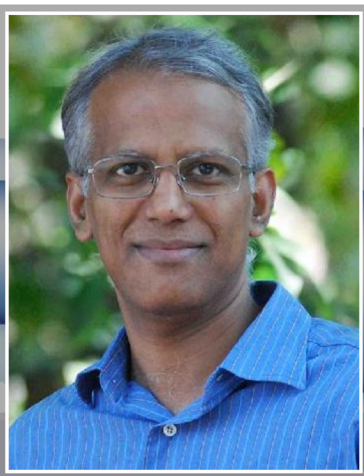
Photocatalysis is an advanced oxidation process, which has shown to possess an enhanced capability to remove a wide range of contaminants from aqueous effluents. We are interested in using novel photocatalysts for inactivation of microorganisms as well as exploring the potential of photocatalysis in reduction reactions.

Ph: +91 80 2293 3108

modak@iisc.ac.in

Prabhu R Nott

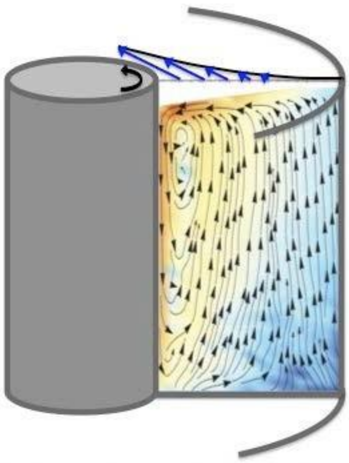
Professor
PhD, Princeton University



Research:

We are interested in the mechanics of complex fluids, such as dry granular materials (food grains, pharmaceutical powders, etc.) and particle-fluid suspensions (slurries, paints, etc.). Understanding their flow and dynamics is of tremendous practical benefit, as they occur in many industrial processes and natural phenomena. Moreover, they pose interesting scientific challenges. We try to build reliable continuum mechanical descriptions, and test them by conducting simple yet probing experiments and particle dynamics simulations. We try to achieve an understanding of the macroscopic behaviour by relating them to phenomena at the microscopic scale.

We are also interested in the collective dynamics of swimming microorganisms. We are now studying the interplay between signalling and motility, and to the collective phenotypic changes that occur over long time-scales. Such an understanding has significant technological value, as microbial biofilms are thought to be responsible for many infections, and resist the action of antibiotics.



The secondary flow observed when a granular material is sheared in a cylindrical device. Adapted from Krishnaraj & Nott, Nature Comm. (2016)

Courses:

CH 206 Seminar Course

CH 243 Mechanics of Particle Suspensions

CH 234 Mechanics of Granular Materials

Selected Publications:

1. Nambiar, S., Nott P. R. & Subramanian, G., "Stress relaxation in a dilute bacterial suspension ", J. Fluid Mech. 812, 41-64 (2017).
2. Krishnaraj, K. P. & Nott, P. R., "A dilation-driven vortex flow in sheared granular materials explains a rheometric anomaly", Nature Commun. 7, 10630 (2016).
3. Gutam, K. J., Mehandia, V., & Nott, P. R. "Rheometry of granular materials in cylindrical Couette cells: anomalous stress caused by gravity and shear", Phys. Fluids 25, 070602 (2013).
4. Mehandia, V., Gutam, K. J. & Nott, P. R. "Anomalous stress profile in a sheared granular column", Phys. Rev. Lett. 109, 128002 (2012).
5. Nott, P. R. "Boundary conditions at a rigid wall for rough granular gases", J. Fluid Mech. 678, 179–202 (2011).

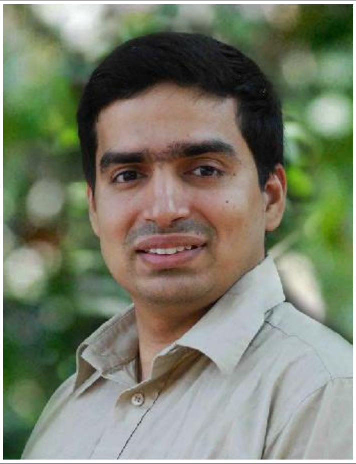
Books:

1. Rao, KK and Nott, PR An introduction to granular flow, Cambridge University Press (2008).

Ph: +91 80 2293 2317
prnott@iisc.ac.in

Sudeep N Punnathanam

Associate Professor
PhD, Purdue University



Courses:

CH 206 Seminar Course

CH 204 Thermodynamics

CH 247 Introduction to Molecular Simulations

Selected Publications:

1. P.K. Bommineni and S. N. Punnathanam, "Molecular simulation of homogeneous crystal nucleation of AB2 solid phase from a binary hard sphere mixture", J. Chem. Phys. 147, 064505 (2017)
2. P.K. Bommineni and S. N. Punnathanam, "Enhanced nucleation of protein crystals on nano-wrinkled surfaces", Farad. Discuss., 186, 187-197 (2016)
3. S. Ravipati and S. N. Punnathanam, "Improving the Rigor and Consistency of the Thermodynamic Theory for Clathrate Hydrates Through Incorporation of Movement of Water Molecules of Hydrate Lattice", J. Phys. Chem. C, 119, 12365-12377 (2015)
4. S. Ravipati and S. N. Punnathanam, "Calculation of three-phase methane-ethane binary clathrate hydrate phase equilibrium from Monte Carlo molecular simulations", Fluid Phase Equil., 376, 193-201 (2014)
5. S. N. Punnathanam, "Simulation of electric double layer capacitors (EDLC) in the constant voltage Gibbs ensemble", J. Chem. Phys., 140, 174110 (2014)

Research:

The research in our group is directed towards understanding the relationship between macroscopic thermodynamic behavior and microscopic interactions using the principles of statistical mechanics. The physical insights gained from such studies can help us in developing molecular theories to determine thermodynamic properties. They also aid in the development of molecular models to predict bulk behavior using molecular simulations. Our current focus is on understanding solid-fluid equilibrium in nanoparticle suspensions, thermodynamic behavior of gas-hydrate systems, thermodynamics of adsorption in microporous materials such as zeolites and metal-organic frameworks (MOFs), and molecular modelling of electric double layer super capacitors. The primary tools used in our research include molecular simulations (both Monte Carlo and molecular dynamics) and density functional theories.

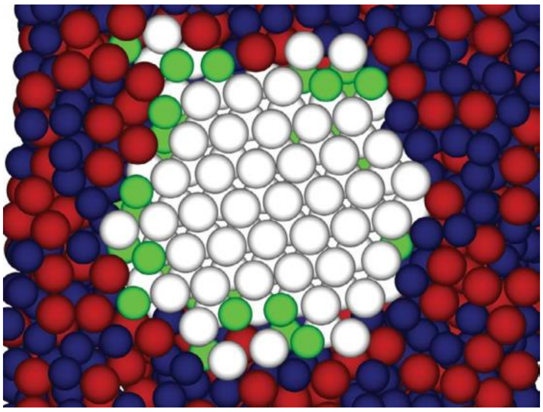
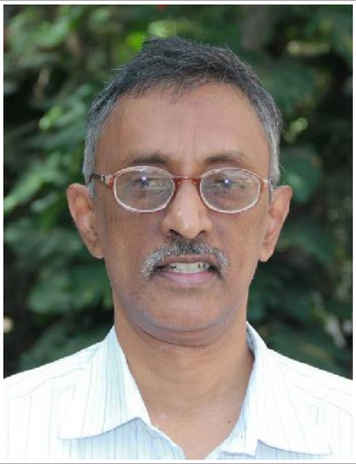


Figure shows a plane cut through the critical nucleus of a eutectic system of binary hard spheres. The hexagonal ordering of a 111 crystal plane, particle A (white) and particle B(green) is evident in the cluster.

Ph: +91 80 2293 3109
sudeep@iisc.ac.in

K Kesava Rao

Professor
PhD, University of Houston



Research:

Our major research interests concern engineering and design of processes and tools for treatment of water from various sources to make them compatible for human consumption or environmental release. One main theme has been defluoridation of drinking water where we have shown how column design and choice of adsorbents are critical to the output water quality. Our studies showed that the surface of the activated alumina pellets undergoes changes upon pre-soaking with deionzied water, possibly caused by a phase transition from boehmite to gibbstie. We demonstrated a strong effect of pre-soaking and column diameter on the volume of treated water obtained from column experiments.

On another front, we have demonstrated the use a solar still for the treatment of drinking water, rainwater harvesting, and efficient disposal of spent analytical reagent at the laboratory scale. Water samples distilled in an inclined-basin solar still displayed successful reduction of total dissolved solids, total hardness, calcium hardness as well as fluoride levels to within the desirable limits for drinking water. Rainwater harvested from the upper surface of the still had water quality parameters comparable to those of bottled water, but the amount of total dissolved solids was much lower. Concerns with the water odour were successfully addressed by replacing sand layer with activated carbon. We are also interested in the reuse of greywater discharged from washing machines for flushing toilets.

Ph: +91 80 2293 2341
kesava@iisc.ac.in

Awards:

Fellow, Indian Academy of Sciences, 1992

Courses:

CH 205 Chemical Reaction Engineering

CH244 Treatment of Drinking Water

Selected Publications:

1. L Anjaneyulu, EA Kumar, R Sankannavar, and KK Rao, Use of a solar still for defluoridation of drinking water and rainwater harvesting, Ind. Eng. Chem. Res. 51, 8040-8048, (2012).
2. R Balakrishnan, R Sankannavar, and KK Rao, A mechanism for the occurrence of ions in distilled water, Ind. Eng. Chem. Res. 50, 13202-13209, (2011).
3. Rohit, L Kanwar, and KK Rao, A low-cost portable colorimeter for the estimation of fluoride in drinking water, Sensors and Actuators B, 149, 245-251, (2010).
4. ML Dhoriyani, KK Jonnalagadda, RK Kandikatla, and KK Rao, Silo music: sound emission during the flow of granular materialsthrough tubes, Powder Techol. 167 55-71, (2006)

Books:

1. Rao, KK, and Nott, PR, An Introduction to Granular Flow, Cambridge University Press (2008).

Rahul Roy

Associate Professor

PhD, University of Illinois, Urbana-Champaign

Awards:

Wellcome Trust - DBT India Alliance Intermediate Fellowship, 2013

Innovative Young Biotechnologist Award, Department of Biotechnology, India, 2013

Jane Coffin Childs Memorial Post Doctoral Fellowship, 2008-2011

Courses:

CH 205 Chemical Reaction Engineering

CH 248 Molecular Systems Biology

CH 249 Structural and Functional DNA Nanotechnology

MB 207 DNA-Protein interaction, Regulation of gene expression, Nanobiology

Selected Publications:

1. ZW Zhao*, R Roy*, JCM Gebhardt*, DM Suter*, AR Chapman and S Xie, Spatial organization of RNA polymerase II inside a mammalian cell nucleus revealed by reflected light-sheet super-resolution microscopy PNAS (USA), 111(2):681-6 (2014) * equal contribution
2. GQ Tang, D Nandakumar, RP Bandwar, KS Lee, R Roy, T Ha and SS Patel, Relaxed rotational and scrunching changes in P266L mutant of T7 RNA Polymerase reduce short abortive RNAs while delaying transition into elongation PLoS One, 9(3): e91859 (2014)
3. R Roy, Next generation optical microscopy, Current Science, 105(11):1524-36 (2013)
4. JCM Gebhardt, DM Suter, R Roy, ZW Zhao, AR Chapman, S Basu, T. Maniatis and S Xie, Single-molecule imaging of transcription factor binding to DNA in live mammalian cells, Nature Methods, 10(5):421-6 (2013).
5. R Zhou, A Kozlov, R Roy, J Zhang, S Korolev, T Lohman and T Ha, SSB Functions as a Sliding Platform that Migrates on DNA via ReptationÓ Cell, 146(2): 222-32 (2011).

Research:

My research programme aims to innovate and engineer novel technologies to help understand and manage infectious diseases using single molecule detection, single cell analysis, quantitative genomics and high-resolution imaging. Using highly sensitive detection of single biological macromolecules like proteins or nucleic acids by both optical and non-optical methods, we determine the molecular behaviour at the single molecule level as well as its distribution at the population level.

New Tools for Probing and Quantifying Biomolecules at the Single Cell and Single Molecule Level

We have been extending single molecule based imaging and spectroscopic techniques like single molecule Förster resonance energy transfer (FRET), single molecule protein induced fluorescence enhancement (PIFE), single particle tracking and super-resolution microscopy that allow quantification of cellular composition even for low copy number constituents, rapid live cell imaging with high-resolution spatial localization. As part of the larger goal to understand cellular heterogeneity, we have developed a high throughput Lab-on-Chip device to quantify absolute copy number of nucleic acids in single cells.

Understanding Principles of Macromolecular Self-Assembly

Another key research focus is in the area of understanding self-assembly of bio-macromolecular structures, we have been pursuing studies of 2D assembly of bacterial pore forming toxins and 3D assembly of viruses/bacteriophages. For pore-forming toxins from bacteria, we find the first set of conformational changes that ensure protein insertion into bilayer membranes is enhanced by the presence of cholesterol. Cholesterol is a key mammalian cell membrane constituent that is absent in bacterial membranes can explain how these proteins selectively puncture across mammalian cell membranes. Separately, we monitor bacteriophage assembly on live bacteria using super-resolution microscopy allowing us to probe key steps in the assembly of bacteriophages that are biotechnologically relevant.

Understanding Virus Infection Using Quantitative Single Virus Sequencing and Modeling

RNA viruses propagate as a quasispecies of closely related genotypes in the host. This helps the virus in rapid adaptation, acquiring drug resistance and fast expansion. Sequence diversity and virulence of a viral species is regulated by the host selection pressures at different levels of its life cycle. Our main objective here has been to define such genetic contributions of the full-length virus genome to its infectivity, which is term as "infectivity fitness". To probe the sequence-infection relationship, we have developed a method that would give us the sequence of each individual viral RNA molecules along with quantitative copy numbers and thereby providing the tools to track the sequence variations in a viral population. Combined with data at various stages of virus infection and modeling of the viral RNA as a substrate for the various viral processes allows us to quantify and model virus dynamics during its lifecycle.

Ph: +91 80 2293 3115

rahulroy@iisc.ac.in

Bhushan Toley

Assistant Professor

PhD, University of Massachusetts, Amherst

Research:

The overarching theme of the research conducted in our lab is the development of new and enabling technologies for biomedical research and medical diagnostics. We give particular emphasis to development of simple and low-cost technology that can be used at or delivered to low-resource settings e.g. rural areas and lightly-equipped clinical or research laboratories. We are currently interested in the two broad areas mentioned below:

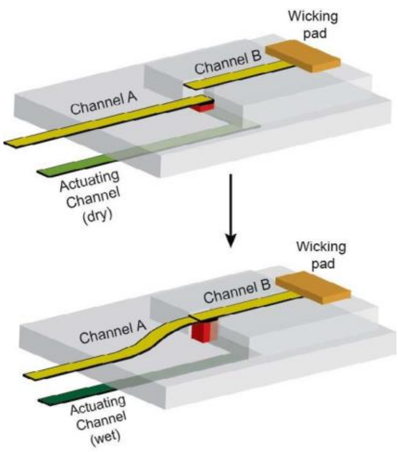
1. Point-of-care medical diagnostics

For a better and healthier future, state-of-the-art medical diagnostic technology must be accessible at the point-of-care, i.e. in close proximity to where the patient is receiving care. However, this requirement is currently far from fulfilled. In India, every year ~1 million people are infected by the TB-causing bacteria *Mycobacterium Tuberculosis.* The state-of-the-art in rapid detection of TB is by using molecular methods, i.e. detecting the bacteria directly by their DNA. However, molecular diagnosis requires very expensive instruments that are not accessible to most in the country. We aim to develop simpler, smaller, and cheaper medical diagnostic devices that can match the performance of state-of-the art instruments. We think of such devices as mini chemical plants and apply fundamentals from chemical engineering and other engineering disciplines to build sophisticated, yet simple-to-use biomedical devices.

One of the areas of focus is the use of paper as a material that can provide pump-less flow of fluid by capillary action. We have developed several new strategies to control and automate the flow of fluids through paper-microfluidic devices, which enable conducting multi-step fluidic operations in power-free devices.

2. Tools for cancer therapeutics development

The cancer drug development process has historically relied on flat plate cultures of cancer cells to test the efficacy of drug candidates. These flat plate cultures do not accurately mimic the complex 3D tumor microenvironment. We aim to develop new simple methods for creating 3D cancer tissues *in vitro.* Our goals are to develop tools that can be more effectively used to screen cancer drugs, can be used to understand the distribution of cancer drugs within 3D tumor tissue, and can be used to answer fundamental questions about the behavior of cancer cells in 3D tumor microenvironments.



The figure shows a power-free paper-microfluidic ON-switch realized by using an expandable sponge actuator.

Ph: +91 80 2293 3114

bhushan@iisc.ac.in

Awards:

Isenberg Scholar Award awarded by the Isenberg School of Management at UMass Amherst

Selected Publications:

1. "A rapid, instrument-free, sample-to-answer nucleic acid amplification test", Lab on a Chip, 2016, 16(19), 3777-3787

   Lafleur LK, Bishop JD, Heiniger EK, Gallagher RP, Wheeler MD, Kauffman PC, Zhang XH, Kline EC, Buser JR, Kumar R, Byrnes SA, Vermeulen N, Scarr NK, Belousov Y, Mahoney W, Toley BJ, Ladd PD, Lutz BR, Yager P
2. "Isothermal Strand Displacement Amplification (iSDA): A rapid and sensitive method of nucleic acid amplification for point-of-care diagnosis", Analyst, 2015, 140, 7540-7549

   Toley BJ, Covelli I, Belousov Y, Ramachandran S, Kline E, Scarr N, Vermeulen N, Mahoney W, Lutz BR, Yager P
3. "A versatile valving toolkit for automating fluidic operations in paper microfluidic devices", Lab on a Chip, 2015, 15, 1432-1444.

   Toley BJ, Wang JA, Gupta M, Buser JR, Lafleur LK, Lutz BR, Fu E, Yager P
4. "Tunable delay-shunts for paper microfluidic devices", Analytical Chemistry, 2013, 85(23), 11545-11552

   Toley BJ, McKenzie B, Liang T, Buser J, Yager P, Fu E
5. "Microfluidic technique to measure intratumoral transport and calculate drug efficacy shows that binding is essential for doxorubicin and release hampers Doxil", Integrative Biology, 2013, 5, 1184-1196

   Toley BJ, Tropeano Lovatt ZG, Harrington JL, Forbes NS

S Venugopal

Associate Professor
PhD, Purdue University

Awards:

Humboldt Research Fellowship for Experienced Researchers, 2013-14

Associate, Indian National Academy of Sciences, 2009

Selected Publications:

1. S. Kumar and V. Santhanam, "Inkjet Printed Electroadhesive Pads on Paper", Int. J. of Nanotechnology. 14 (9-11), 859- 866 (2017)
2. P. Joshi and V. Santhanam, "Paper-based SERS Active Substrates on Demand", RSC Advances. 6 (72), 68545-68552 (2016)
3. I. Banerjee, V. Kumaran, and V. Santhanam, "Fabrication of Electrodes with Ultralow Platinum Loading by RF Plasma Processing of Self-Assembled Arrays of Au@Pt Nanoparticles", Nanotechnol. 27, 305401 (2016)
4. I. Banerjee, V. Kumaran, and V. Santhanam, "Synthesis and Characterization of Au@ Pt Nanoparticles with Ultrathin Platinum Overlayers", J. Phys. Chem. C, 119 (11), 5982-5987 (2015)
5. S.K. Parmar, and V. Santhanam, "In situ formation of silver nanowire networks on paper", Curr. Sci. 107(2), 262-269 (2014).

Patent:

1. V Santhanam, SK Sivaraman, "Methods for preparing metal and metal oxide nanoparticles", US 8361188

Research:

An underlying theme of research activities in our group is the development of a process engineering toolkit that will enable the use of metal nanoparticles as building blocks for applications in the fields of sensing, energy conversion, and nanoelectronics. We have developed a scalable process for the formation of robust arrays of metal nanoparticles on any desired substrate. This has aided in the fabrication of several devices such as floating gate memory devices, flexible SERS (Surface Enhanced Raman Scattering) substrates and PEMFC (Proton Exchange Membrane Fuel Cell) catalyst layers. Currently, we are working on fabricating chemiresistive sensors and nanowire array based photoelectrodes for DSSCs. Furthermore, a room-temperature process for the synthesis of monodisperse metal nanoparticles in colloidal form was developed and patented. Based on the insights gained, we are now working on novel reactor designs for high-throughput, continuous flow synthesis of monodisperse metal nanoparticles. We have also discovered a simple process for fabricating conductive electrodes on paper using an office inkjet printer. Presently, we are working on utilising such conductive films to develop low-cost products for water filtration, medical diagnostics and ubiquitous sensing.

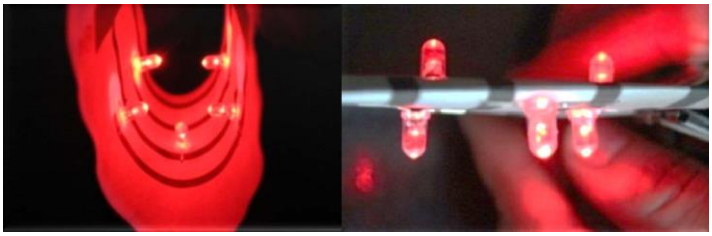
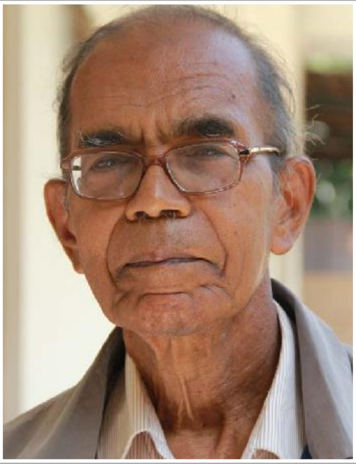


Figure shows five LEDs "stapled" onto a conductive electrode circuit printed on paper. A 700 nm thick layer of silver nanowires was deposited using a commercial office inkjet printer.

Ph: +91 80 2293 3113
svgpal@iisc.ac.in



M Chanda

Emeritus Professor
PhD, Indian Institute of Science

Ph: +91 80 2293 3107
chanda@chemeng.iisc.ernet.in

Research:

Polymer science and technology
Ion-exchange technology
Waste water treatment
Solar desalination

Awards:

I.E.L. Award for Excellence in Process Development from the Indian Institute of Chemical Engineers, 1988

International Scientific Exchange Award from National Sciences and Engineering Research Council of Canada, 1980, 1982, 1983, 1985,1988, 1990, 1992

Fellow, Indian National Academy of Engineering, 1992

Biographical sketch in Marquis Who's Who in the World, Millennium Edition, 2000, American Biographical Society

Publications:

1. M Chanda, A Sarkar and JM Modak, Ethoxylated polyethylenimine gel-coated on textile-grade acrylic fiber: a thermally regenerable superfast sorbent for water desalination. J. Appl. Polym. Sci. 93, 883-893, (2004)
2. M Chanda and G L Rempel, A superfast sorbent based on textile-grade polyacrylonitrile fiber/fabric: rapid removal of uranium from mildly acidic aqueous solutions of low concentration. Ind. Eng. Chem. Res. 42, 5647-5655, (2003).
3. M Chanda and G L Rempel, A new method of gel-coating polyethylenimine (PEI) on organic resin beads: high capacity and fast kinetics of PEI gel-coated on polystyrene. Ind. Eng. Chem. Res. 40, 1624-1632, (2001).
4. M Chanda and G L Rempel, A gel-coated ion-exchange resin: a new kinetic model. Chem. Eng. Sci. 54, 3723-3733, (1999)
5. S Naskar, SA Pillai, and M Chanda, Photocatalytic degradation of organic dyes in aqueous solution with TiO2 nanoparticles immobilized on foamed polyethylene sheet. J. Photochem. Photobiol. A 113, 257-264, (1998).

Books:

1. M Chanda Introduction to Polymer Science and Chemistry: A Problem-Solving Approach, 2nd Ed. CRC Press Taylor & Francis Group (2013)
2. M Chanda and SK Roy, Plastics Technology Handbook, 4th Ed., CRC Press Taylor and Francis Group (2007)

Research:

Modelling of electrochemical power sources, specially lead-acid batteries, lithium ion batteries and fuel cells, is the focus my research. Performance of fuel cells and batteries depends upon a balance of electrocatalytic properties of electrodes, ionic and electronic resistance of electrodes and electrolyte, and diffusion of active ingredients participating in the electrochemical conversion reactions that generate power. Apart from this, management of thermal effects and electrolyte distribution are some other important factors that determine performance. Batteries have a finite life since electrodes, which are porous, degrade. Degradation could be due to several causes. Some of them are: mechanical failure caused by fatigue, alteration of the porous structure which prevents access to reactive materials and regeneration of reactive materials during charging cycles outside electrodes. I use mathematical modelling to address these issues as it can be a powerful tool for design, and diagnostics of performance as well as degradation.

K S Gandhi

Professor (Retired)
PhD, University of California, Berkeley

Ph: +91 80 2293 2320
gandhi@iisc.ac.in

Awards:
Dr B P Godrej Life Time Achievement Award, 2011
Fellow, Indian National Academy of Engineering, 2003
Fellow, Indian Academy of Science, 1990

Courses:
CH 245 Computational Transport Phenomena

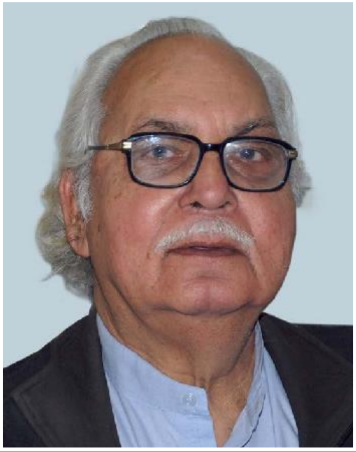
Publications:

1. KS Gandhi, Use of Fick's Law and Maxwell--Stefan Equations in Computation of Multicomponent Diffusion A.I.Ch.E. Journal 58(11), 3601-05, (2012).
2. KS Gandhi, Storage of electrical energy. Indian Chemical Engineer, 52(1), 51-75, (Text of Prof HL Roy memorial lecture delivered in CHEMCON 2009, Visakhapatnam) (2010).
3. KS Gandhi, Modelling of freezing phenomena induced by chemical reactions Ind. Engg Chem. & Res 48(21), 9755-9762, (2009).
4. KS Gandhi, AK Shukla, SK Martha, and SA Gaffoor, Simplified mathematical model for effects of freezing on the low-temperature performance of the lead-acid battery. J. Electrochem. Soc. 156(3), A238-A245, (2009).
5. Sanjeev Kumar, KS Gandhi, and R Kumar, Modelling of formation of gold nanoparticles by Citrate Method. Ind. Engg Chem. & Res 46, 3128-3136 (2007).

Books:
1. KS Gandhi, Heat & Mass Transfer: A Transport Phenomena Approach, 1st Ed., New Age Publishers, Delhi (2011)

Research:

Multiphase phenomena
Dispersion of fluids in liquids from submerged nozzles
Engineering analysis of foam beds
Analysis of turbulent stirred dispersions
Bio-leaching of copper from lean ores
Multicomponent Precipitation involving small systems
Analysis of sonochemical reactors



Rajinder Kumar

Honorary Professor
PhD, Punjab University

Ph: +91 80 2293 3109
kumar@iisc.ac.in

Awards:

Padma Bhushan awarded by President of India, 2003
Prof NR Das memorial lecture, NASc, 1997
Shanti Swarup Bhatnagar Award, INSA, 1997
Jawaharlal Nehru Birth Centenary Visiting Fellowship, INS, 1995
FICCI Award for Physical Sciences, 1994
Alumni Award for excellence in Research in Engineering, Indian Institute of Science, 1991
Shri Om Prakash Bhasin Award for Engineering, 1991
Syed Hussain Zaheer Medal for Engineering and Technology by INSA, 1989
Dr. KG Naik Gold Medal given by M.S.University of Baroda, 1988
Vasvik Award, 1986
Herdilia Award for `Excellence in Basic Research', given by IIChE, 1985
Bhatnagar Prize for Engineering Sciences, given by CSIR, 1976
Fellow, Indian National Academy of Engineering, Indian Academy of Sciences, Indian National Science Academy

Publications:

1. R Bandyopadhyaya, R Kumar and KS Gandhi, Modelling of $CaCO_3$ nanoparticle formation during overbasing of lubricating oil additives. Langmuir 17, 1015-1029 (2001).
2. R Bandyopadhyaya, R Kumar and KS Gandhi, Simulation of precipitation reactions in reverse micelles. Langmuir 16, 7139-7149 (2001).
3. D Niyogi, R Kumar and KS Gandhi, Water blown free rise polyurethane foams. Polym. Engg. Sci. 39, 199-209 (1999).
4. S Kumar, V Ganvir, C Satyanand, R Kumar and KS Gandhi, Alternative mechanisms of drop breakup in stirred vessels. Chem. Eng. Sci. 53, 3269-3280 (1998).
5. R Rajan, R Kumar and KS Gandhi, Modelling of sonochemical oxidation of CCl_4 in aqueous solutions Environ. Sci. Tech. 32, 1128-1133 (1998).

Technical Officers

B.G. Girija
Scientific Assistant
girija@iisc.ac.in

Support Staff

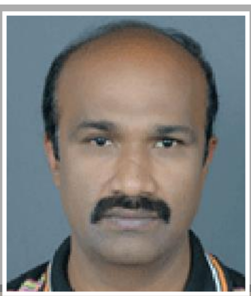
Vajrappa
Supervisor
vajrappa@iisc.ac.in

Narayanappa
Supervisor
narayanappa@iisc.ac.in

Mahadavappa S
Mechanic

Muni Lakhsmamma
Multi Task Staff (MTS)

Other Staff



Venkata
secretariat assistant
venkataiah@iisc.ac.in

Deepak
Office Assistant
mdeepak@iisc.ac.in

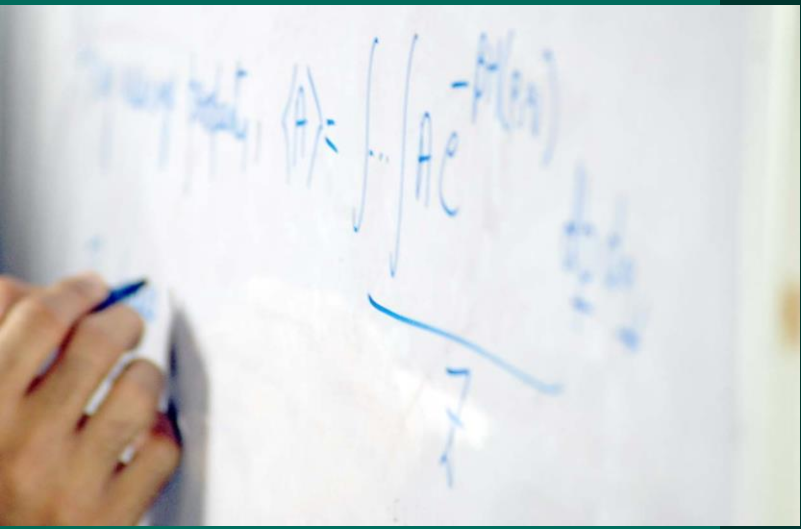
Lakshmi.R
Secretariat Assistant
lakshmi@iisc.ac.in

maheshwari
Secretariat assistant
maheswari@iisc.ac.in

Courses

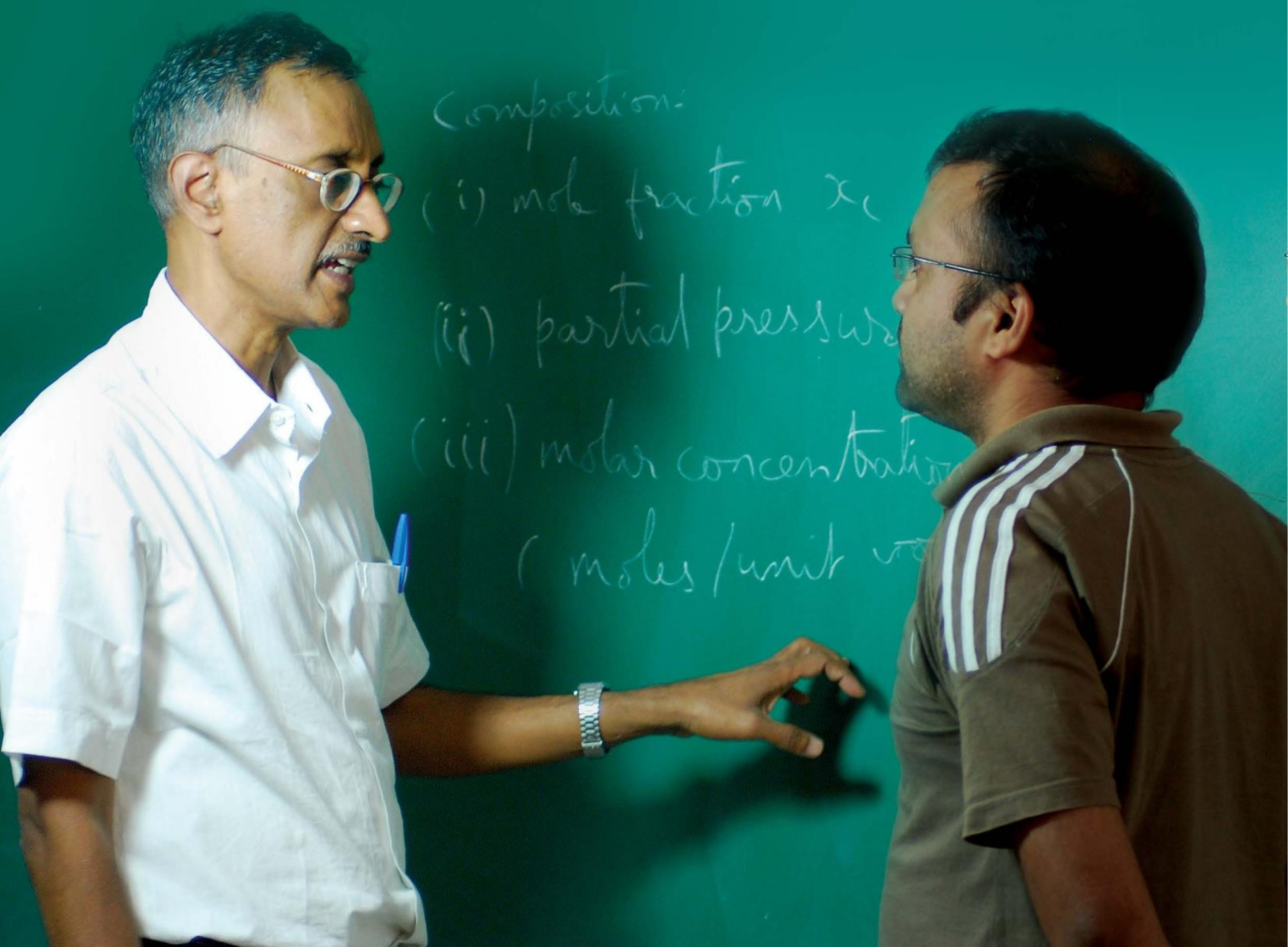
CORE COURSES

CH 201	3.0	Chemical Engineering Mathematics
CH 202	3.0	Numerical Methods
CH 203	3.0	Transport Processes
CH 204	3.0	Thermodynamics
CH 205	3.0	Chemical Reaction Engineering
CH 206	1.0	Seminar Course
CH 207	1.0	Applied Statistics & Design of Experiments
CH299	32.0	Dissertation Project



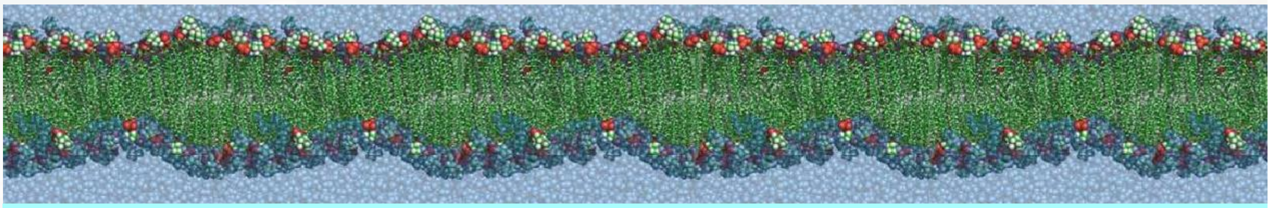
ELECTIVES

CH 232	3.0	Physics of Fluids
CH 233		Interfacial and Colloidal Phenomena
CH 234	3.0	Mechanics of Granular Materials
CH 235	3.0	Modelling in Chemical Engineering
CH 236	3.0	Statistical Thermodynamics
CH 237	3.0	Polymer Science and Engineering
CH 239	3.0	Modern Instrumental Methods of Analysis
CH 242	3.0	Special Topics in Theoretical Biology
CH 243	3.0	Mechanics of Particle Suspensions
CH 244	3.0	Treatment of Drinking Water
CH 245	3.0	Computational Transport Phenomena
CH 248	3.0	Molecular Systems Biology



Conferences and Workshops

The Department of Chemical Engineering and ChemE professors frequently organize international/national conferences and workshops in coordination with other units. The diversity and breadth of the meetings and its participants reflects the diverse interests of the department researchers. They provide a platform for leading national and international researchers to come together and also germinate successful international collaborations.



INDO-US Symposium On Structure, Dynamics & Mechanics of Biological Membranes

at Indian Institute of Science, Bangalore, December 29-31, 2012

http://chemeng.iisc.ernet.in/biomem/index.html

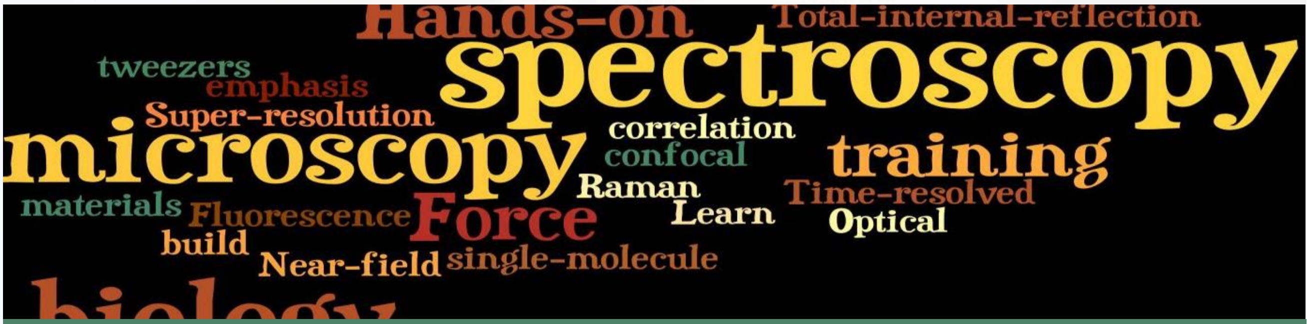
The underlying relationships between the structure, dynamics, and mechanics of biological membranes were discussed by scientists from U.S.A. and India engaged in cutting-edge research in the fundamental and applied aspects of bio-membrane research.

International Conference on Population Balance Modelling PBM 2013

at Indian Institute of Science, Bangalore, September 11-13, 2013

http://chemeng.iisc.ernet.in/pbm2013/

Researchers interested in using population balance modelling and its application to disease progression, understanding of biological systems, mining, control of wastewater treatment, nanoparticle synthesis processes, and chemical processing industry came together. More complex systems, solution and simulation strategies, mono and multivariate size distribution dependent model based control actions were discussed over three days.



National Fluorescence Workshop FCS 2013

at Indian Institute of Science and Jawaharlal Nehru Centre for Adanced Scientific Research, Bangalore November 24-28, 2013

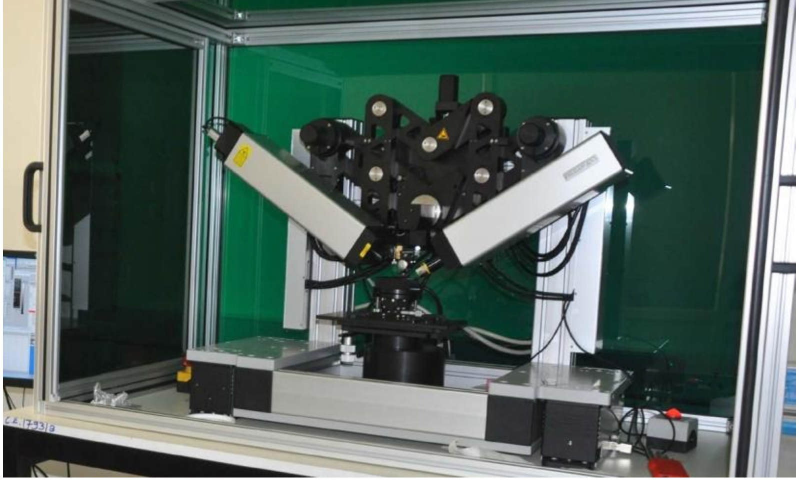
http://chemeng.iisc.ac.in

FCS-2013 is intended to focus on in-depth theoretical training and hands-on exploration of emerging techniques in fluorescence and Raman spectroscopy for biology and material science. Apart from research and didactic talks, satellite sessions will provide hands-on training on construction of confocal and total-internal-reflection microscope from generic parts.

Facilities

Building

The Department of Chemical Engineering is located in the heart of the IISc campus. Originally constructed in the 1960s, the building has been significantly renovated in recent times. Spanning about 15000 square feet of experimental laboratory space and 5000 square feet of office space, class room and conference rooms, the department houses twelve experimental and computational laboratories. Two cleanrooms (400 square feet, Class 10000; 225 square feet, Class 100000) are available in the department for nanomaterial synthesis/analysis and single molecule imaging. The department has its own library-cum-lounge as well as computer lab for student study and discussion.



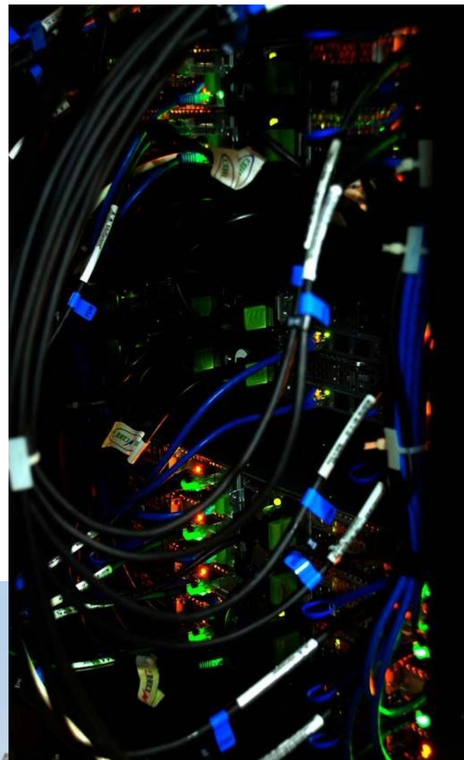
Computing facilities

The department has excellent computational facilities that cater to the research needs of the faculty and the students. The department computer laboratory houses state-of-the-art computers equipped with the latest software packages that can support specialized applications including CFD modelling as well as plant and reactor design.

Advanced computational facilities in individual research groups including six highly customized in-house computer clusters devoted to research are available.

Experimental facilities

With several experimental groups sharing the resources in the department, the experimental facilities have grown and evolved over the years and the department now houses advanced spectroscopy, chromatography, imaging and material property measurement instruments from a variety of sources. It also houses a large collection of chemical and biochemical reactors which are regularly used for experimental investigations.



"The rigorous course work and research training that I obtained in IISc are the best I could have hoped for. They prepared me well for my post-doctoral research at Minnesota, as well as for my current position at IIT Kanpur.

My best non-academic experience was the very-friendly student crowd (at least in my times), where one could call upon anyone for a cup of coffee at any time of the day (or night!) and discuss research and other struggles in the life of a graduate student."

vshankar@iitk.ac.in

V. Shankar
Professor, IIT Kanpur

Ganesh A Viswanathan
Assistant Professor, IIT Bombay

"I have been conducting fundamental research (towards PhD, postdoc and research at IITB). The emphasis on fundamental research laid out via various courses and research training during MSc (Engg) at IISc has been of tremendous help in all the post IISc pursuits so far. I enjoyed Prof. Gandhi's modelling course and Prof. Kesava Rao's heat and mass transfer course. These courses gave a good flavor of how to come up with a hypothesis for a given problem."

ganeshav@iitb.ac.in

"I give full credit to ChemE, IISc for shaping up my career in R&D. I have worked with Dow Chemicals previously and with Shell for last 7 years and I still feel that the education I got from ChemE dept is very useful in my job. I had a short industrial experience before joining IISc however after completing masters from IISc my career has scaled to different height. The research oriented syllabus, excellent coaching & guidance, high standards in exams etc. were quite useful. The passion for technical stuff acquired in ChemE IISc, helped me in surviving in the R&D field."

saurabh.kaujalgikar@gmail.com

Saurabh Kaujalgikar
Process Technologist, Shell Bangalore

Girish M
Research Scientist, Unilever R&D Bangalore

"Its a wonderful place with lots of freedom and great atmosphere to do research. As many feel, the importance of IISc will be felt only after we leave the place. During my academic period, I used to wonder when i am going to submit my thesis. But now, i keep remembering those wonderful nights at IISc, which is totally absent in corporate world."

girish1984@gmail.com

"I completed both masters and PhD from the chemical engineering department at the IISc. The interest each faculty member shows in training a student towards conducting research is phenomenal. The very fundamental questions raised in day to day life by my colleagues and the faculty at the department made me think in the right direction of solving important research problems. With the training I was provided with, now I am very much excited to contribute my part to science and hence to the society, as a post doctoral fellow at the MIT, Boston."

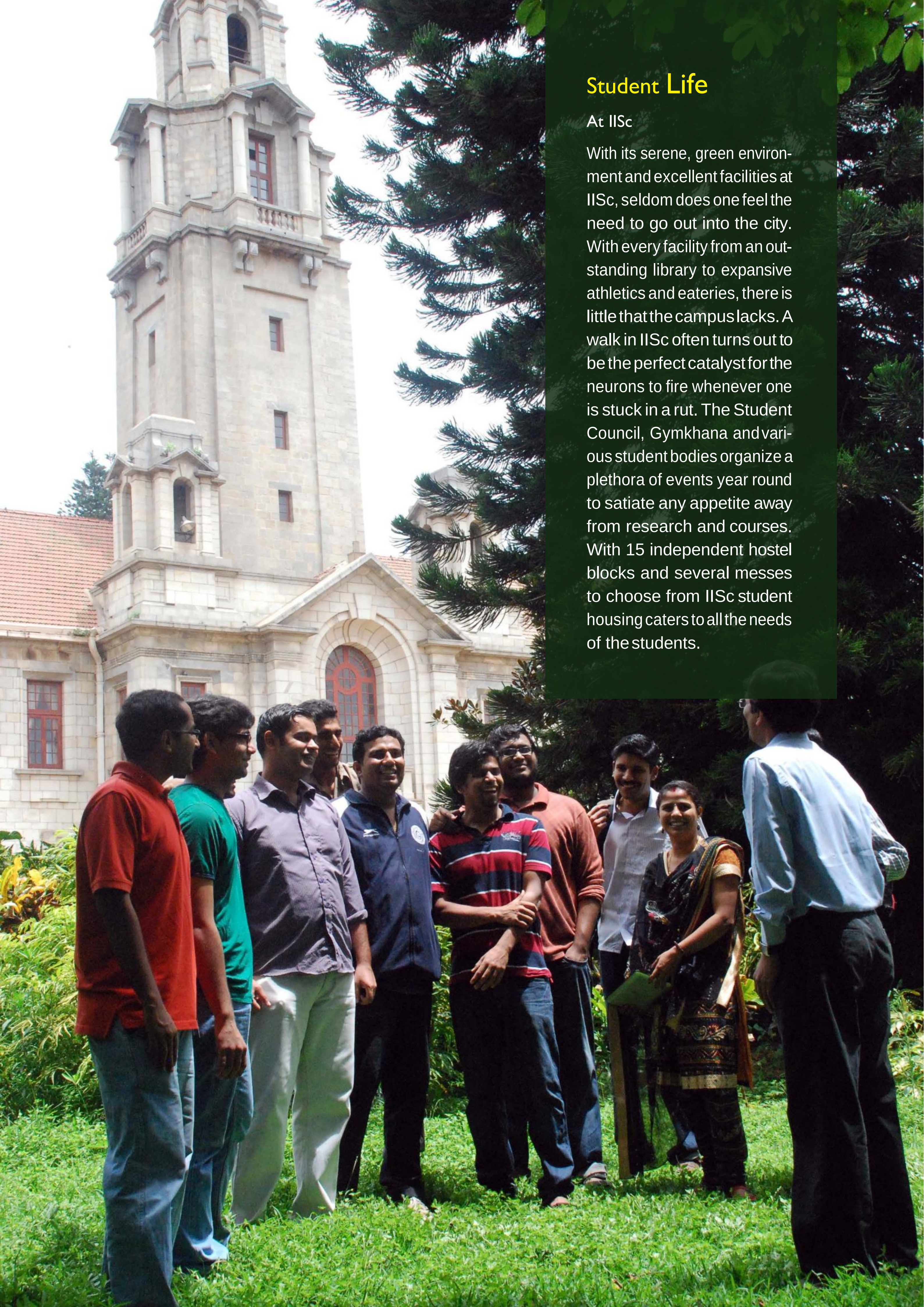
siva.perala@gmail.com

Siva Rama K Perala
Post Doctoral Fellow, MIT Cambridge

Student Life

At IISc

With its serene, green environment and excellent facilities at IISc, seldom does one feel the need to go out into the city. With every facility from an outstanding library to expansive athletics and eateries, there is little that the campus lacks. A walk in IISc often turns out to be the perfect catalyst for the neurons to fire whenever one is stuck in a rut. The Student Council, Gymkhana and various student bodies organize a plethora of events year round to satiate any appetite away from research and courses. With 15 independent hostel blocks and several messes to choose from IISc student housing caters to all the needs of the students.



Chemical Engineering Association

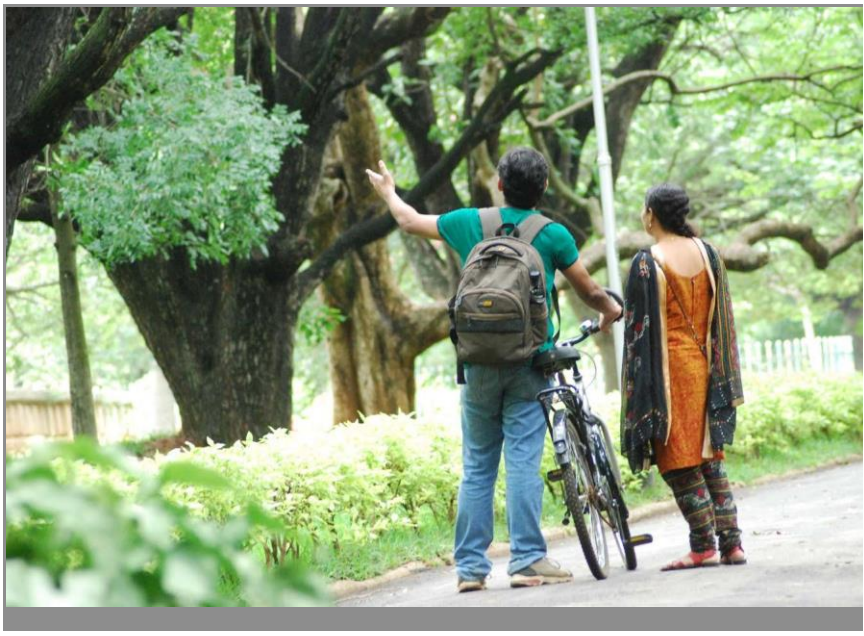
CEA serves as a common platform for ChemE students alums and faculty to get together. CEA organizes lectures, field trips, outreach programmes, sporting events, a cultural night and annual symposia generating a vibrant and enriching environment for all. CEA also serves the additional role of liaison between the current students and the alumni of the Chemical Engineering department. The best part about CEA is that it is an organization of the ChemE students run almost independently by the students and hence providing extensive opportunities for honing leadership qualities and promoting professional growth while having fun with your friends and colleagues.

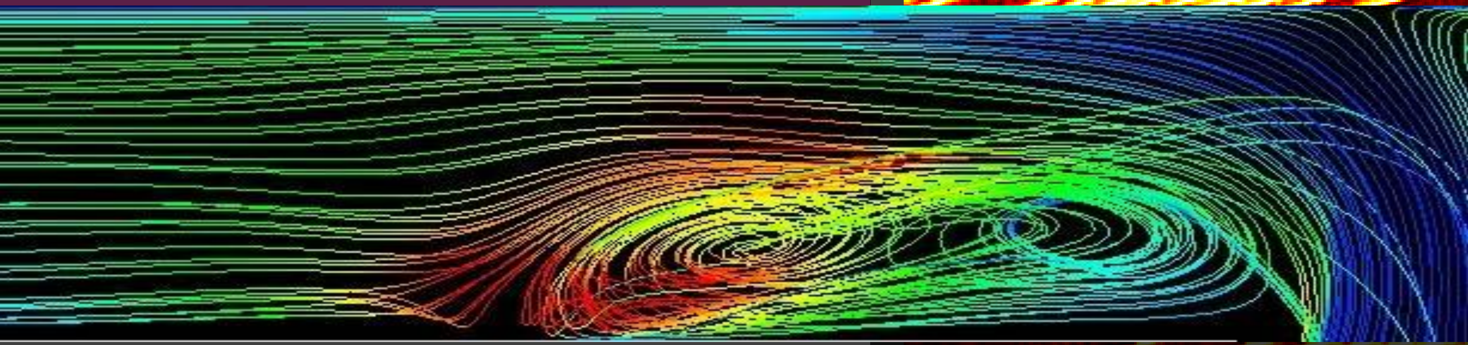
In the department

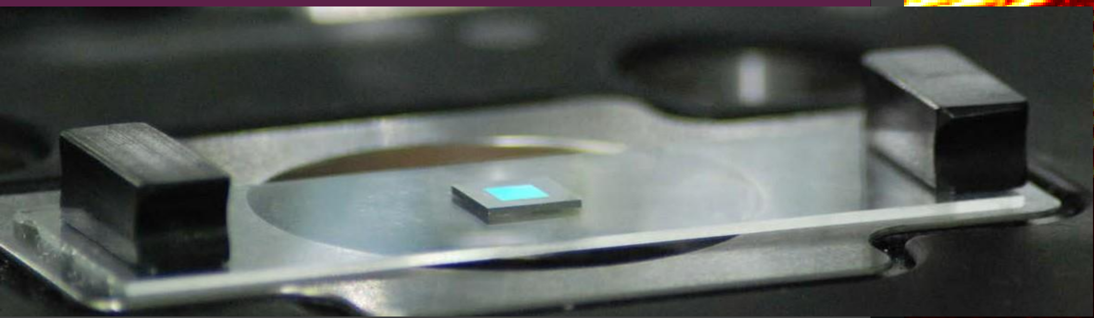
Students find the ChemE faculty to be friendly and genuine in their intentions. While the course work and research is rigourous and demanding, ChemE professors are easily accessible for conceptual doubts or suggestions related to research. The small size of the ChemE department means a very familiar and pleasant environment for all where one is able share thoughts (and not just pertaining to research or science) over a cup of coffee in the library cum lounge. The academic freedom in framing their own research problems and then addressing with various techniques makes it an extremely rewarding journey. The existing camaraderie among the students effectively makes the department their second home.

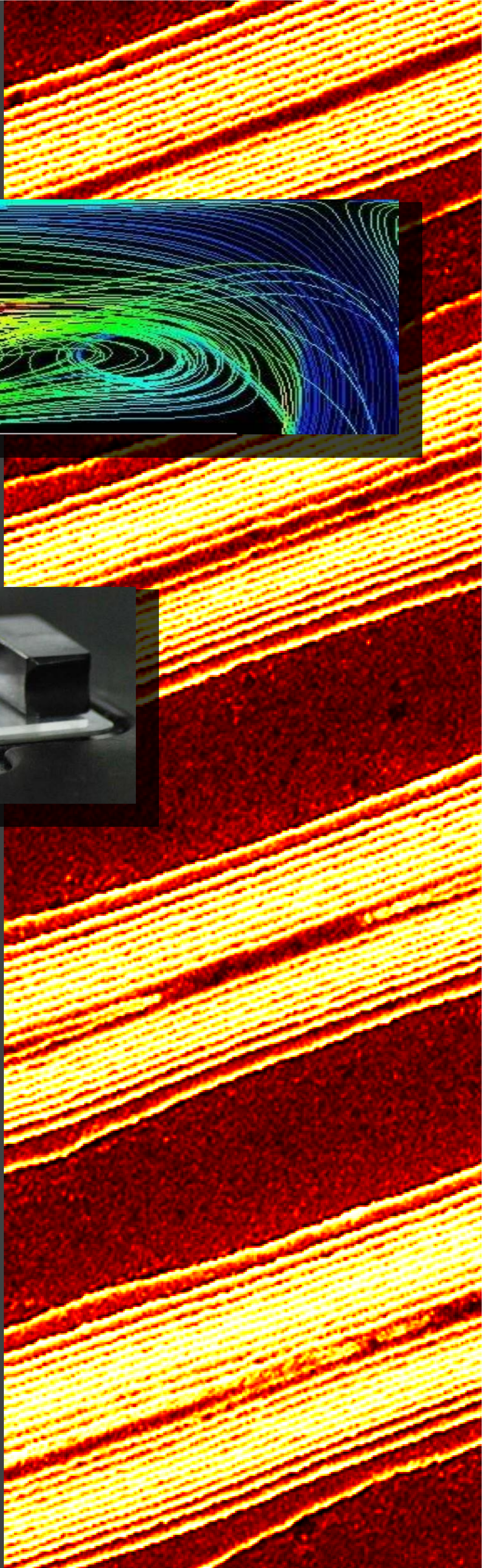
Bangalore and beyond

Bangalore is an exciting cosmopolitan city with many major industrial, commercial and educational centers. Nicknamed as 'Silicon Valley of India' on one hand to signify its global IT-industry and 'Garden City' on the other, it resembles the struggles of a new city that is trying to maintain its historical integrity under perpetual growth. The beautiful and equitable climate, beautiful gardens, parks and natural lakes, provide ample opportunities for sight-seeing. Bangalore is also famous for its shopping malls, bustling plazas, bars and restaurants that are favorites among the students. Apart from the nearby city of Mysore, the Shivanasamudra Falls, Ranganathittu Bird Sanctuary, Nagarhole and Baneeerghtta National Parks are some of the attractions for the wild-at-heart.









Designed by:
Naina (Sai Maa) • Vadhana V • Rajat Desikan • Ayush Agrawal • Rahul Roy