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R&D Newsletter

Indian Institute of Technology Kanpur

Science & Technology for Sustainable Future

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Highlight of the Issue

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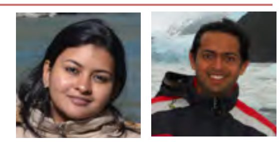
National Science Day Celebration

National Science Day is celebrated in India every year to mark the discovery of the Raman effect by Sir CV Raman. **IIT Kanpur** celebrated **National Science Day** on February 28, 2018. A thematic workshop on 'Science and technology for a Sustainable Future' had been organised by the Centre for Environmental Science and Engineering (CESE). Faculty members from the thematic area were invited to give popular talk on the related research areas. Highlights of those presentations are presented here.

Linkage between Indian Summer Monsoon and Melting Himalayan Glaciers



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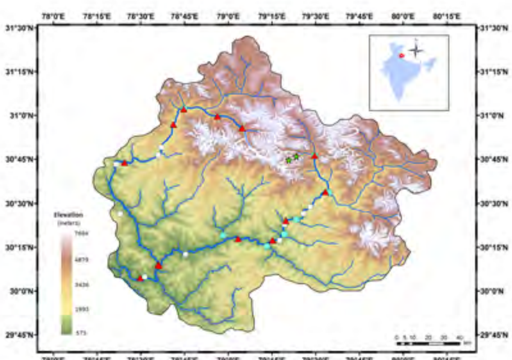
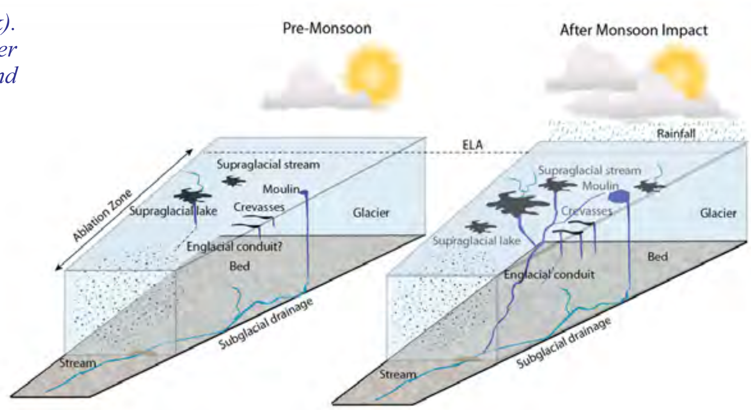
Himalayan glacier meltwater, combined with Indian Summer Monsoon (ISM) precipitation, feeds many large river systems that provide water security to ~750 million people in South Asia. However, the role of the ISM rainfall on Himalayan deglaciation, and its effect on stream hydrology is poorly constrained. In this study,



Topographic map of Ganges headwater basin (outlined in black). Sampling locations: white triangles and yellow circles are river water samples, red squares are ground water samples and green stars are glacier samples

we use oxygen and hydrogen isotope fingerprinting technique to characterize the water sources in the nine headwater tributaries of the Ganges River. River water samples were collected in three seasons (pre-monsoon, monsoon, post-monsoon) over various stages of the annual hydrologic cycle between 2014 and 2016. In addition to river water, ground water, snow, and glacier ice samples were also collected. Isotope fingerprinting technique revealed that post-monsoon (October and November) discharge consistently delivers the highest glacier meltwater proportions compared to discharge during pre-monsoon (April and May).

This observation is contrary to the notion that glacier melt proportions are highest during the pre-monsoon or summer months due to elevated temperatures leading to higher glacier melt runoff. To explain the observed high glacier melt proportions in all the headwater tributaries of Ganges during post-monsoon months, we propose that monsoon rainfall acts as a trigger for enhanced melting and helps developing an efficient englacial drainage network for melt water transport. The heat released by rainfall cooling and freezing within glaciers causes enhanced melting, while opening of the englacial conduits creates an efficient englacial drainage network. We estimate that heat released by rainfall cooling and freezing could produce 3-12% of total discharge at the glacier snout. Our findings indicate that ISM rainfall is an important, yet unrecognized driver of elevated glacier melt runoff in the Himalayan Rivers.



A Conceptual overview of the glacier body during pre-monsoon, after the rainfall impact during ISM

Noble Photocatalytic Systems for Degradation of Organic Compounds towards Wastewater Treatment Applications

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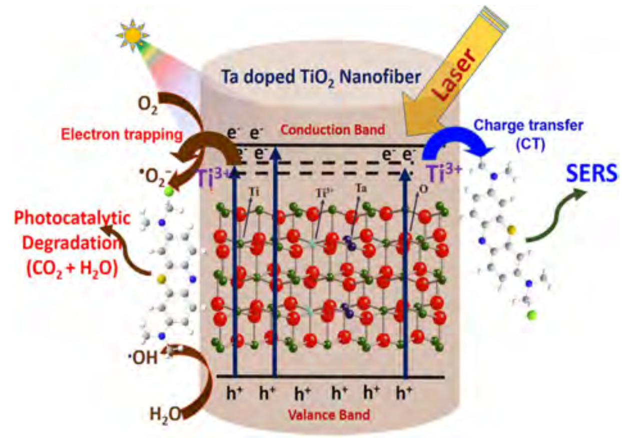
Water pollution is an emerging problem across the world due to rapid population growth and modern industrialization. It not only affects human health, but also causes problems for aquatic life and animals. Waste water contains organic (such as phenolic derivatives, polycyclic aromatic hydrocarbons etc.) and inorganic compounds which can cause serious disorder. Photocatalysis is a prominent process for water purification utilizing solar energy. ZnO and TiO_2 are well known photocatalysts to degrade organic and inorganic pollutants. However, these materials still require modifications with other nanomaterials because these materials absorb only ultraviolet part of sun light due to wide bandgap and the excitons created under the UV light rapidly recombine. In our group, we have developed various nanostructured TiO_2 based photocatalysts such as nanoparticles, nanofibers etc. and further enhanced their photocatalytic activity for degradation of organic compounds through sensitization with carbon dots/quantum dots, doping with transition metals and functionalization with core-shell metal nanoparticles. Enhancement in visible light absorption as well as in charge separation at the interface was obtained through these modifications. These materials are reusable and their nanostructures do not change after repetitive usage. The current research focus of the group is to develop visible light activated low-cost and scalable photocatalysts to treat effluent water from industries in particular, pharmaceutical and tannery.



Development and Performance Evaluation of a High Volume Indigenous Fine Particle Sampler

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The development and lab performance of a high volume (Q = 950 LPM), multiple slit nozzle-based $PM_{2.5}$ (particle aerodynamic diameter < 2.5 μm) inertial impactor was highlighted in the presentation. Lab experiments were performed on various slit-based nozzle impactors using polydisperse dolomite powder as test aerosol. After carrying out rigorous parametric evaluation, the optimum slit nozzle-based impactor configuration selected had cutoff size of 2.51 μm (aerodynamic diameter) at an operating flow rate of 215 LPM (medium flow) with a pressure drop of 0.35 kPa across the impactor stage. The length of the slit of this optimum medium flow impactor was extrapolated to a flow rate of 950 LPM to obtain the high volume multiple slit nozzle-based $PM_{2.5}$ inertial impactor assembly. This novel impactor assembly was fabricated from brass and chrome-plated and then retrofitted in a high volume dust sampler (Model AAS 217NL, Ecotech Instruments, India) downstream of the PM_{10} cyclone separator. High vacuum silicone grease was used as the impaction substrate. A field study was performed as part of M.Tech. (EEM) thesis of Mr. Anand Kumar with co-located novel high volume impactor assembly (HVIA) and single stage low flow rate $PM_{2.5}$ impactor, to not only compare the $PM_{2.5}$ mass concentrations but elemental, anion and water soluble organic carbon (WSOC)/water soluble inorganic carbon (WSIC) concentrations as well in order to validate the HVIA developed in the present study. This study was funded by BRNS and after completion three such high volume retrofitted $PM_{2.5}$ samplers were installed at BARC and this technology was successfully transferred to BARC, Mumbai.

Figure 1. Indian Patent filed for Multiple Slit Nozzle-based High Volume PM2.5 Impactor Assembly developed in this study

Green Energy: Hydrogen Storage Systems

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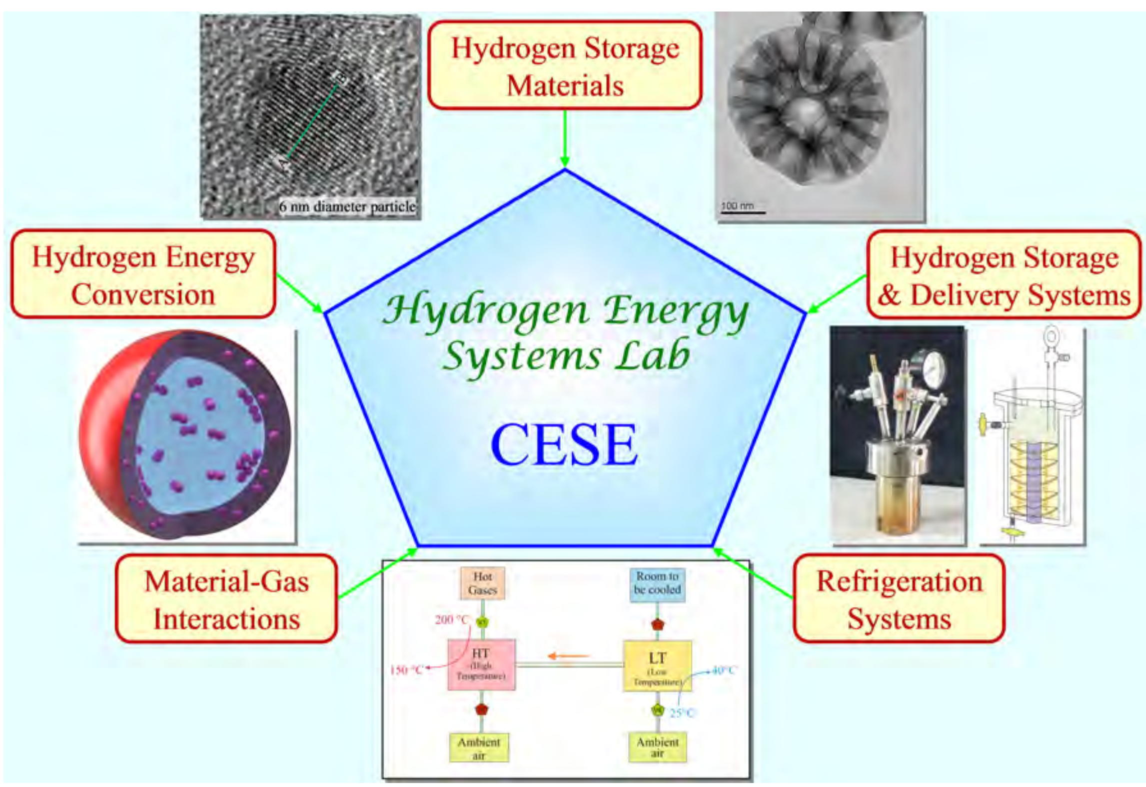
The age of fossil fuels is slowly coming to an end and research on alternate energy sources has taken centre stage. Entire "hydrogen economies" have been envisaged and storage of hydrogen is an important component towards the use of hydrogen as an alternate "clean fuel". Storage of hydrogen in materials has received tremendous thrust in the past few decades, given its advantages like safety and high energy density.

A hydrogen storage system has three important components:

- Material,
- Storage & Retrieval,
- Safety features.

Important classes of materials developed for hydrogen storage include: (i) metals and alloys (intermetallics), (ii) carbonaceous materials, (iii) metal organic frameworks, (iv) zeolites & (v) clatherates. In the research work in progress, the horizons of these materials are being enhanced via concepts like "microstructurally engineered nano-hybrids" and "multi-mode hydrogen storage". One of the thrust areas under the theme is green refrigeration technology; wherein waste heat of an IC engine is used to drive a metal hydride based hydrogen storage system.

As a part of the National Science Day celebrations the hydrogen energy related activities at the Hydrogen Energy System Lab, Centre for Environmental Sciences (CESE) was highlighted. I.I.T. Kanpur (coordinated by Dean Research & Development) was the nodal agency for the nationwide Technology Systems Development program of DST. Ten organizations across the country participated in the research project, which not only established IITK as a major player in the area of hydrogen research, but also gave considerable impetus to the field in the country. These initiatives are expected to contribute to environmental and energy sustainability.



Restoring National Air Resources: Challenges to Solutions

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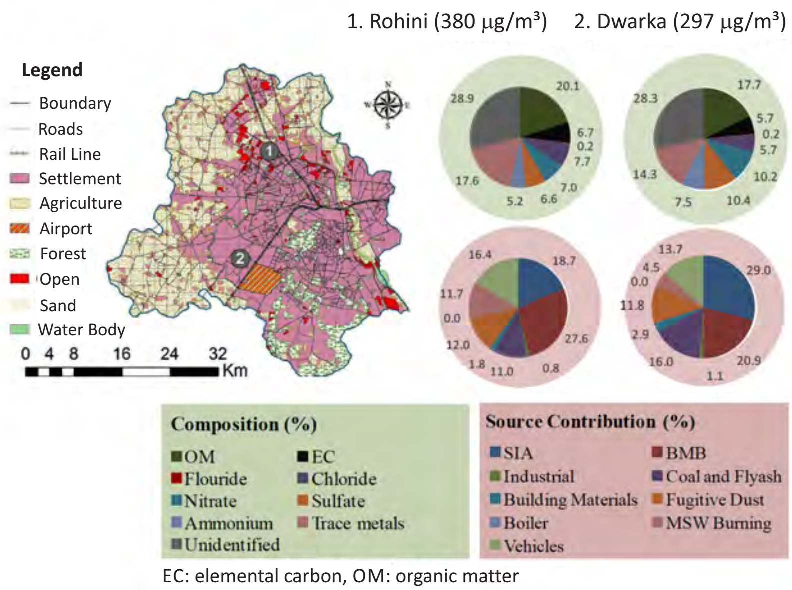
Air pollution poses a major risk to human health, and by reducing air pollution, we can significantly reduce the burden of many diseases such as stroke, heart disease, lung cancer and respiratory diseases. Many Indian cities show extreme pollution levels, at times, 5 to 7 times higher than the national air quality standards. The first two weeks of November in 2016 and 2017 witnessed high air pollution episodes in the City of Delhi and many other cities in north India; most of the Indo-Gangetic Plain looked hazy, and people complained burning sensation in eyes. Ordinary citizens are puzzled as to what is being done to mitigate air pollution and where are the results? The problem is multi-dimensional, where scientists and decision-makers will have to work in tandem. Solutions require sound scientific basis, right policies and financial resources. There are anthropogenic and natural causes for bad air quality; large-scale urbanization, industrialization, land use changes, biomass and fossil fuel burning, constrained dispersion due to geographical features like valleys and lack of year-round rains. The complicated large-scale phenomena make the problem challenging. Before one decides on engineering solutions, the fundamental task is to develop a causal linkage between emitting sources and their relative impacts on air quality at a receptor.



Chemical composition and source contributions to $PM_{2.5}$ in Delhi at Rohini and Dwarka (numbers in parenthesis show $PM_{2.5}$ concentration; National standard: 60 µg/m3)

Emission reduction at source is fundamental as pollutants once in the atmosphere; there is very little that one can do. Mathematical models, on-field measurements and chemical composition of pollutants are frequently used to identify and to adopt the emission reduction strategies. There are two modeling approaches: (i) dispersion and (ii) receptor-source. While dispersion modeling solves the advection-diffusion mass balance equation, receptor modeling starts with observed ambient airborne pollutant concentrations at a receptor. The receptor model seeks to apportion the observed concentrations among several sources based on the knowledge of the chemical and physical composition of the emissions, and by comparing it with the chemical composition obtained at a receptor. The receptor-source model, employing Chemical Mass Balance (CMB) approach (e.g. USEPA CMBv8.2), has been applied to many air quality problems, which delineates the contribution of various sources at a receptor.

To provide technical support to policy makers, a framework including air quality monitoring, detailed pollutant characterization, identification of sources and their contributions to ambient air pollution was developed and implemented for the City of Delhi. The figure above shows chemical composition and average CMB-computed source contributions to $PM_{2.5}$ (particles of a size of less than or equal to 2.5 micron-meter) at two receptor locations. There are exciting findings; in addition to vehicles, secondary inorganic aerosol (SIA; aerosol formed in the atmosphere through the interaction of precursor gases), biomass burning (BMB including crop residue), municipal solid waste (MSW) burning, dust and construction activities are important sources. These sources often get ignored, and emission reductions on pre-perceived sources do not necessarily translate in improved air quality.

The above findings and inputs from other institutions were seminal in drawing the action plans for Clean Transport, Clean Fuel, and Biomass Management under CII-NITI Aayog-led, 'Cleaner Air Better Life Initiative'. The implementation of these plans will ensure clean and healthy air for many years to come. This research is a prime example of how sound science-based investigations could impact policy in a meaningful way.

Processes Governing the Fate and Transport of Inorganic Pollutants in Groundwater and their Remediation

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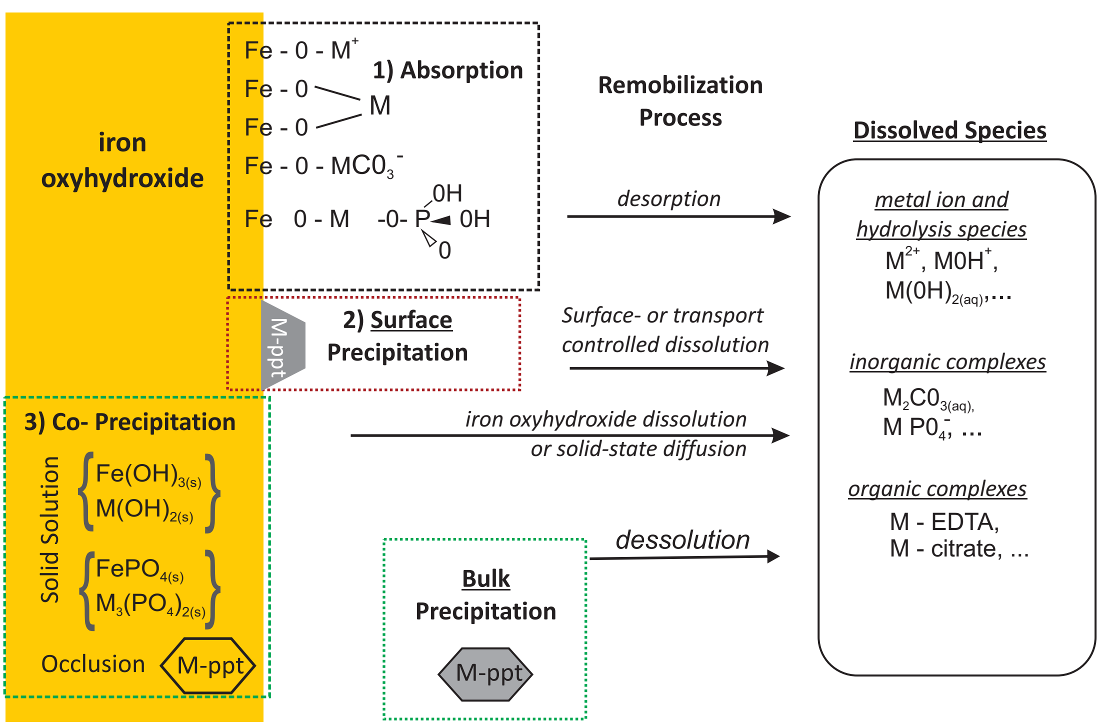
Groundwater is currently the largest source of freshwater for the rural (~80%) and urban (~50%) Indian population. The availability and purity of this resource has been limited by past anthropogenic activities such as mining, processing, and waste disposal that have left a legacy of severely contaminated groundwater and soil. Research at the Environmental Geochemistry Lab (EGL) in the Centre for Environmental Science and Engineering (CESE) involves quantifying the extent and forms of hazardous pollutants like arsenic, chromium, fluoride or uranium in typical groundwater of Indo-Gangetic basin and identifying the likely sources of pollution – chromium has industrial origin while fluoride has geogenic origin. This knowledge is helpful to understand the contaminant fate and transport of these materials and develop in situ methodologies to remediate the contaminated zones. A part of this remediation effort also involves characterization and stabilization of hazardous wastes to find ways to recycle and reuse them gainfully in Civil Engineering applications.

Broadly, the research focuses on developing meaningful interfaces between fundamental science and applied research and engineering to develop solutions that ultimately could be translated to the field. At a fundamental level, we are interested in investigating the physical and chemical processes occurring at the mineral-water interfaces such as adsorption, precipitation, and reduction-oxidation (Figure below), to gain a clear understanding of the geochemical factors for contaminant uptake, their stability and conditions for remobilization. Specifically, experimental and associated modelling approaches for remediation of excessive fluoride, chromium and other heavy metals in Indo-Gangetic groundwater are being attempted.

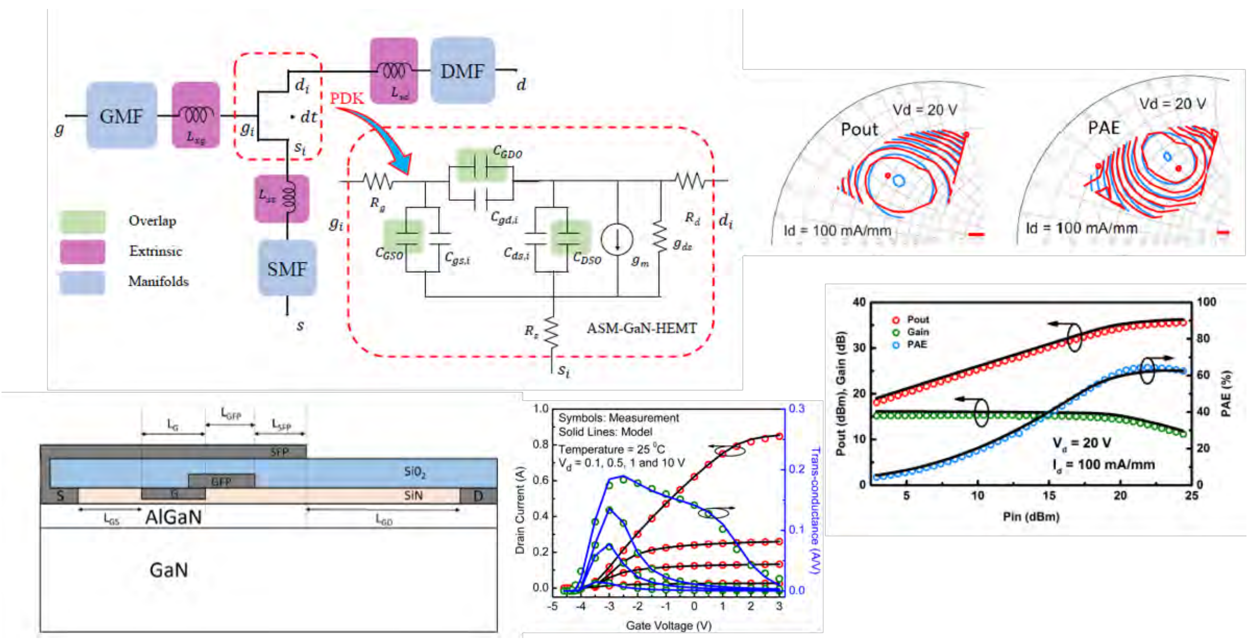


Immobilization mechanisms and remobilization processes for a divalent contaminant, M. 1) Adsorption as monodentate, bidentate, and ternary surface complexes; 2) Precipitation of discrete phases at the surface, which may become occluded within the substrate; 3) Co-precipitation to form a solid solution or occluded phases; 4) Bulk precipitation. Chemical and physical remobilization processes are determined by the immobilization mechanism.

ASM-HEMT: Advanced SPICE Model for Gan HEMTs

The SPICE model (Titled: ASM-HEMT) developed by **Prof. Yogesh Chauhan**, Department of Electrical Engineering and his collaborator has been selected as the world's first industry standard model for Gallium Nitride High Electron Mobility Transistor (GaN HEMT) by Silicon Integration Initiative's Compact Model Coalition (CMC). Industry standard models are selected after rigorous evaluation and validation on multiple technologies by the semiconductor industry. This work is an outcome of the last six years' effort of Prof. Chauhan's group. The model will now be available in Electronic Design Automation software and it will be used by major semiconductor and EDA companies worldwide. GaN HEMT is widely used in RF power amplifiers and power electronics applications. GaN HEMTs will be key to design power amplifiers for future 5G technology.

The GaN HEMT technology is of special significance to India. Government of India is considering to setup a GaN foundry near Bengaluru. DRDO and ISRO are also actively working on developing this technology for defence and space applications. Prof. Chauhan is working with both of these agencies in developing SPICE models for circuit design using GaN HEMTs.



Prof. Sathesh Mariappan, Department of Aerospace Engineering has been jointly awarded an **International Exchanges award** by the Royal Society as overseas collaborator with his principle collaborator and Investigator Prof. Maria Heckl, Keele University UK. This is envisaged to enhance UK-India research collaboration.

Foundation for Innovation and Research in Science and Technology (F.I.R.S.T.)

The incubation and innovation ecosystem at IIT Kanpur goes for a major makeover. A not-for-profit company, F.I.R.S.T., Foundation for Innovation and Research in Science and Technology, has been created to run the SIDBI Innovation and Incubation Center from April 01, 2018.

F.I.R.S.T. is envisioned as a bridge between technology start-ups & Micro, Small and Medium Enterprises (MSME) and the incubation ecosystem at IIT Kanpur comprising of around eleven incubators and five prototype and testing labs. The Board of Directors consists of noted entrepreneurs, industrialists, industry leaders and two Institute Nominees. There will also be a highly qualified Board of Mentors, identified by the Board of Directors, and the Chief Operating Officer (COO), who will act as a bridge to connect each entrepreneurial venture with the suitable mentor(s) from this group. Mr. Rajarshi Mukhopadhyay, an alumnus of IIT Kanpur, has been appointed as the COO of F.I.R.S.T.

SIDBI Innovation and Incubation Centre , IIT Kanpur won the **ISGF Innovation Award 2018** under the category pf Smart Incubator of the Year. The award was given by India Smart Grid Forum (ISGF). ISGGF is a Public Private Partnership initiative of Ministry of Power (MoP), Government of India for accelerated development of smart grid technologies in the Indian power sector.

One incubatee startup **Delmos Research** have been chosen winners in Agri sector of the Villgro iPitch contest at an event in Hyderabad today. Delmos are manufactures of fabric strips for testing adulteration in milk. They were selected after several rounds of pitching and due diligence.

Open House Organized by IIT Kanpur for Secondary School Students in Kanpur

IIT Kanpur in partnership with the office of District Inspector of Schools (DIOS), Kanpur organized an open house at the Institute's Flight Lab for secondary school students of Kanpur Nagar on March 24, 2018. Prof. S Ganesh, Dean of Research and Development, and Mr. Vipul Mathur, Chief Engineer, Flight Lab, IIT Kanpur coordinated the event. Various demonstrations were given to the students, explaining the working mechanism of aircrafts, Unmanned Aerial Vehicles and the race car by SAE Club of IITK. Around 650 students from different schools, along with their principals and teachers had been present at this event.

Industry-Academia Collaboration

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