

**Indian Institute of Technology  
Bombay's  
Ideas and Innovations for  
Society**

ज्ञानम् परमम् ध्येयम्



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**I**ndian Institute of Technology  
**B**ombay's  
**I**deas and Innovations for  
**S**ociety



## Director's message

Over the last three decades, IIT Bombay has focused increasingly on Research and Development (R&D), in addition to its core activity of providing a high quality education.

The Institute received more than INR 1300 Crores of funding in the last five years towards research from external agencies and industry. This has enabled setting up of state-of-the-art experimental facilities for research, as well as several major research centres in which students and faculty from different departments work together to address problems in a holistic way.

The output of our R&D efforts include not just publications in research journals but also patents, copyrights and designs, resulting from applied research and design. The Institute has been making efforts to translate this output into use. One of the important metrics of the success of our R&D enterprise is the number of technologies licensed for commercialization. More than 100 technologies and products developed at IIT Bombay have been deployed and we are proud to present a representative set in this brochure.

Besides the technologies contained in this brochure, IIT Bombay has several more technologies that are awaiting deployment (<https://rnd.iitb.ac.in>). Some of these technologies are ready for implementation, while others may need additional work to reach the deployment stage: prototyping, mass production, balancing the cost and quality of the product, etc. These efforts require collaboration between IIT Bombay and the Licensee at the initial stages. We will be happy to partner with entities for translating our technologies to end use.



*Prof. Subhasis Chaudhuri*



## Dean (R&D)'s message

IIT Bombay has always been in the forefront of technology and innovation in India. We continue to be ranked amongst the top technical educational institutes both nationally and globally. IIT Bombay has also been recognized as an Institution of Eminence by the Government of India, validating our performance in imparting a world-class education to our students, and providing an ecosystem that allows them to flourish as world-class academicians, researchers, entrepreneurs and business leaders.

Research and Development (R&D) activities at IIT Bombay kept up a brisk pace with time. Recently, understanding the challenge posed by Covid-19 pandemic, the Institute took up many R&D projects for its mitigation very early on, including seed funding many projects internally. This head start enabled IIT Bombay to come up with various technologies and innovations leading to multiple technology transfers/licensing to many industries / start-ups, some of which have already been commercialized.

Consequently, we at IIT Bombay have seen an exponential growth in the number of intellectual property rights (IPR) applications in FY 20-21 as against the past few years. This rise in numbers is due to filing of IPR

applications for COVID-19 related technologies as well as the significant increase in registration of trademarks and designs. Increase in trademark registrations could be considered as indicator of licensing possibilities of various innovative technologies at IIT Bombay.



With this book, we are showcasing a sample of technologies & innovations and limitless potential that is available at IIT Bombay.

“IBIS” is a compendium of about 100 such technologies that have been developed by IIT Bombay’s faculty members and researchers in recent years. Some of these technologies and know-hows are “ready to go” and it is relatively easier to deploy such innovations but more often than not, innovations need additional efforts to reach commercialization stage.

We look forward to collaborations with industries and external agencies to translate these innovations into viable technologies that can be deployed in the market and society at large. In this 75<sup>th</sup> year of India’s independence, let us move a step closer to Atmanirbhar Bharat.

*Prof. Milind D. Atrey*

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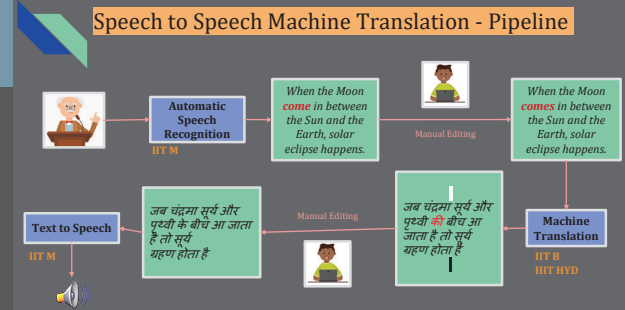
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**AI/ML/Blockchain technologies (including quantum computing)**



## Bahubhashak: Machine Translation involving English and Indian Languages



**Problem Statement:** India is a land of diversity. The vast number of languages spoken in the country is a testimony to this fact. There are four language families, with twenty-two scheduled languages, with more than thirty languages spoken by over 1 million people. This diversity of languages does bring with it a set of challenging tasks. One of them is education, the primary concern being enabling learning in Indian languages. Teaching-learning in one's mother tongue is known to be highly effective. Responding to this challenge, a consortium of institutes consisting of IIT Bombay, IIT Madras and IIIT Hyderabad has created the speech-to-speech machine translation (SSMT) system from English and Hindi to many Indian languages.

**Uniqueness of the Solution:** The researchers aim to build a speech-to-speech machine translation (SSMT) system that will translate speech in English and Hindi into Indian languages,

focusing on educational content. SSMT consists of a pipeline of stages: (i) first the spoken utterance is converted to text (ASR), (ii) then the produced text is translated to the target language text (MT), and (iii) finally, the translated text is rendered into speech (TTS) in the target language. The uniqueness of the system is it can (a) cater to a large number of Indian languages (b) provide high-quality output that overcomes many unique challenges of Indian languages like phonetic, morphological, syntactic complexity, code-mixing, data sparsity and others.

**Current Status of Technology:** A prototype is developed, which is ready for production/deployment.

**Societal Impact:** A system called "AskAgastya", which is a solution to enable children in rural areas to clarify doubts over a phone line has been developed as a prototype. Ask in the local language (ASR), translates and queries

English textbooks, Respond to students in vernacular voice over the phone line. The system can have a tremendous impact on enhanced access to learning in rural areas across the country.

**Patent(s):** Nil

**Relevant Industries:** Science and Technology, Education, IT, Governance & Policy, Judicial System, Tourism.

**Faculty:** Prof. Pushpak Bhattacharyya, Computer Science & Engineering.

## Maximising Computation in Blockchains

**Problem Statement:** Current Blockchain such as Ethereum allocates only a tiny fraction (e.g., less than 1% for Ethereum) of the average block inter-arrival time between blocks for validating smart contracts present in transactions. A trivial increase in the validation time introduces the popularly known Verifier's Dilemma, causes more forking and increases unfairness. Large validation time also reduces the tolerance for safety against a Byzantine adversary. Hence, Blockchains do not allow Computation Intensive Transactions (CIT). Solutions that offload validation to a set of non-chain nodes (a.k.a. off-chain approaches) suffer from trust and performance issues that are non-trivial to resolve. The current approach aims to allow the execution of CIT on the Blockchain without compromising security.

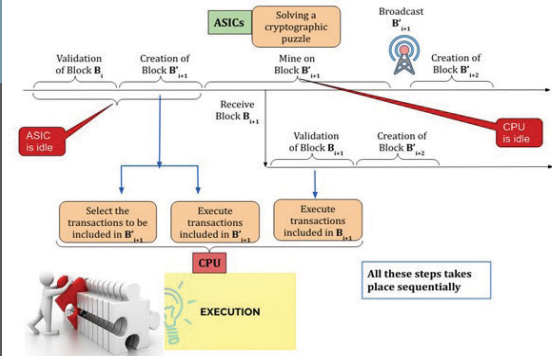
**Uniqueness of the Solution:** For the first time, this research has attempted an on-chain protocol to scale computation to 100% in PoW blockchains theoretically.

The team has also pursued performing CPU-based block processing in parallel to ASIC mining. This is achieved by allowing miners to delay validation of transactions in a block by up to  $N$  blocks, where  $N$  is a system parameter. Researchers have developed a prototype implementation atop Ethereum, which demonstrates that it can scale without suffering the harmful effects of naïve scaling up of computation time in existing blockchains. Security analysis of this approach is also performed considering all possible adversarial strategies in a synchronous network with maximum end-to-end delay " $D$ " and demonstrate that it achieves security equivalent to known results for longest chain PoW Nakamoto consensus.

### **Current Status of Technology:**

Prototype tested and security analysis performance is ongoing.

**Societal Impact:** Scaling computation on blockchain will allow integration of applications using heavy computation



(including those using AI/ML, privacy-preserving cryptography etc.).

**Patent(s):** Filed

**Relevant Industries:** Blockchain, Software, Finance, Banking.

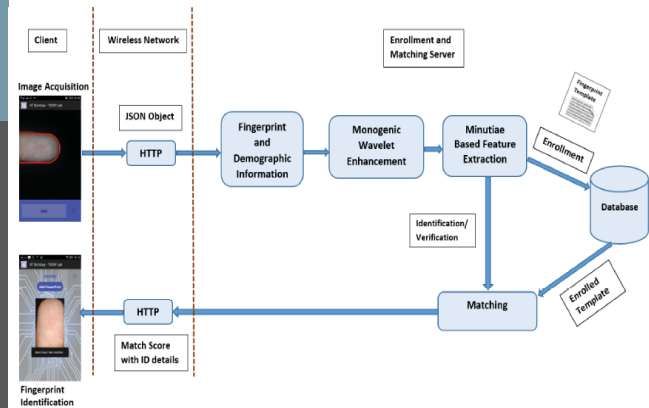
**Faculty:** Prof. Umesh Bellur, Prof. Vinay J. Ribeiro, Computer Science and Engineering.

## Multi-resolution Machine Learning for Touchless Biometric Applications

**Problem Statement:** Biometrics plays a significant role in the security, defence and banking industries. Touchless based biometric authentication at airports, border control, corporate offices and banks have gained more prominence, particularly after the onset of the pandemic. Touchless biometrics are meant to be user-friendly and hygienic. The rising use of smartphones, tablets, various hand-held devices and wearable devices opens a huge market for touchless mobile biometric solutions. Biometrics also has a good share in law enforcement and the healthcare industry. Thus, the researchers are developing touchless biometric identification and verification techniques based on multiresolution machine learning/deep learning techniques. The developed methods can be a possible national resource for use in UIDAI, police, defence establishments, security applications, and use in other corporate/government establishments.

**Uniqueness of the Solution:** The research combines the principles of multiresolution image processing and current machine learning/deep learning techniques. It has the potential to make biometric authentication more robust. Besides, the researchers have tested different kinds of biometric systems, including systems based on the ear, iris, and touchless fingerprints. The most important aspect of this work is that all biometric systems (including fingerprint recognition) are touchless or contactless, an objective that has gained even greater momentum during the days of the pandemic.

**Current Status of Technology:** A prototype mobile app for touchless fingerprint recognition and classification has been built, and it is in the proof of concept stage. In addition, the investigations of biometric systems based on the ear and iris have shown promising results; they are currently integrating them into a software package.



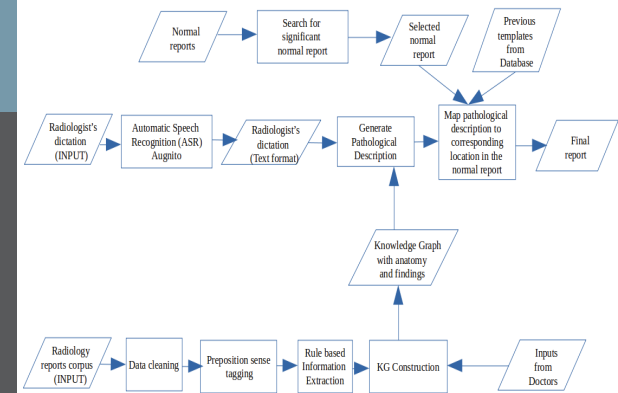
**Societal Impact:** Biometrics can be used to detect fraud. The use of biometrics in security applications will indirectly bring the value of safety and wellbeing to people by its positive consequences in security.

**Patent(s):** Nil

**Relevant Industries:** Security, Defence, Banking, Airports, Healthcare.

**Faculty:** Prof. Vikram M.Gadre, Electrical Engineering.

## Shushrut: Automatic Radiology Report Generation



**Problem Statement:** Generating reports from radiology (XRAY, MRI, CT, UltraSound) plates automatically with high accuracy and speed enables the radiologist to concentrate only on diagnostics. Developing such a system for increasing efficiency and diagnosis-accuracy of clinical workflow in Indian radiology can be possible using automatic speech recognition (ASR) and natural language processing (NLP). Improving productivity of radiologists is equivalent to reaching the US-like ratio of one radiologist per 10,000 people, up from the prevalent Indian condition of one radiologist per 100,000. In such a system, ideally, the input to the system would be (i) input text (spoken form) and (ii) generic radiology report with all normal findings. This system should then give an output that would be a radiology report with patient-specific findings.

**Uniqueness of the Solution:** Shushrut is developed as a solution using ASR and NLP. Structured information from

the free text is found, and a hierarchical knowledge graph is constructed. This knowledge graph is used to convert the radiologist's dictation to pathological description, leading to a huge productivity improvement for radiologists. The speech recognition part has been commercialised under the name Augnito (<https://augnito.ai/>). Shushrut is the next block in the pipeline for converting radiologists' spoken impressions into a full-fledged diagnostic report.

**Current Status of Technology:** Validated/ Developed Technology is currently being used by doctors on trial.

**Societal Impact:** The number of radiology reports that the radiologist can examine is expected to rise ten times due to a reduction in the human-in-the-loop factors and routine and drudgery-full tasks relegated to the machine, thereby increasing the efficiency of radiologists and reducing time.

**Patent(s):** Nil

**Relevant Industries:** Healthcare, Diagnostics, Digital Health Management, Diagnostic Centres.

**Faculty:** Prof. Pushpak Bhattacharyya, Computer Science & Engineering.



## Vajra - Threat Detection and Response in Linux End Points



**Problem Statement:** Malware attacks can put IT infrastructure at risk. Many malware attacks are difficult to detect using standard methods. For example, fileless malware, a recent development, operates in the computer's memory, thus avoiding signature scanners like antiviruses. To bolster security, an IT department may implement various endpoint security solutions over time. However, multiple standalone security tools can complicate the threat detection and prevention process, especially if they overlap and produce similar security alerts. A better approach is an integrated Endpoint Security solution. The current need of the hour is to design a system to quickly detect, analyse, block, and contain attacks in progress. It needs to collaborate with other security technologies to give administrators visibility into advanced threats to speed detection and remediation response times.

**Uniqueness of the Solution:** Existing

endpoint detection and response (EDR) solutions mostly focus on Windows systems, and no comprehensive solution is available for Linux systems. The tool developed by the team focuses explicitly on Linux systems with support for container security. Currently, no indigenous tools on EDR solutions exist, and this tool fills this void. The tool allows system administrators to detect lateral movements and privilege escalation and quickly control the damage. Also, the researchers will be providing continuous R&D support and constantly updating the rule engines to detect and provide protection against new malware.

**Current Status of Technology:** The system prototype is ready and tested in a lab environment. The product will be tested under various operational environments (TRL-6).

**Societal Impact:** Privacy and security are essential aspects that need to be guaranteed to all the users of digital

services. This tool helps keep users' information safe and thus helps build a safer digital society.

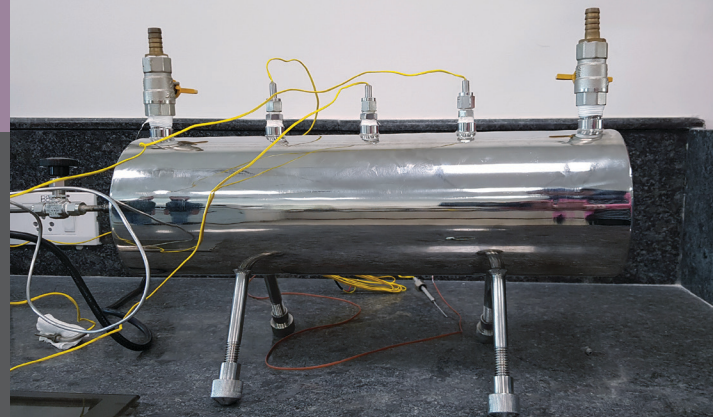
**Patent(s):** Nil

**Relevant Industries:** Cybersecurity, Information and Communication Technology.

**Faculty:** Prof. Manjesh K. Hanawal, Industrial Engineering and Operations Research.

**Clean Energy & Renewables (including Hydrogen and EV)**

## 100 kWh Solid-State Hydrogen Storage Device



**Problem Statement:** Hydrogen storage is the biggest bottleneck in the large-scale usage of hydrogen. Currently, compressed hydrogen is transported in pressurised vessels, whether for vehicular applications or short-distance transport. The pressure is high, ranging from 350 bar to 700 bar. Liquid state storage requires a temperature of 20K (-253°C) and thus needs super-insulated tanks. However, the solid-state storage can be done under normal operating conditions, that is, near room temperature and from 1 bar to around 30 bar pressure. Solid-state hydrogen storage is advantageous because it has high volumetric energy density near ambient operation conditions (temperature and pressure). However, when metal hydrides are used for storage, the hydrogenation and dehydrogenation reactions are exothermic and endothermic, respectively. Thus the device/reactors used for metal hydride based solid-state hydrogen storage should be designed to consider the thermal management

to supply/remove the heat required/generated during these processes.

**Uniqueness of the Solution:** The team simulated solid-state hydrogen storage devices and computationally optimised them to get the best performing designs. They adopted several methodologies to get the optimum device configuration. They fabricated the devices and studied them experimentally for cycling and performance analysis.

**Current Status of Technology:** The team has simulated, optimised and then developed several such solid-state hydrogen storage devices in the laboratory. In addition, they have demonstrated reactors of different sizes like 10 kWh, 30 kWh and 100 kWh, and their applicability for various applications.

**Societal Impact:** Compressed hydrogen tanks for hydrogen storage are currently being imported and are very expensive. The devices that the team has developed

in the laboratory can be used for various applications such as vehicular applications, heating and cooling, backup power, hydrogen compression, hydrogen purification and thermal energy storage. In addition, these devices can be scaled up for various other application requirements.

**Patent(s):** Filed & Granted

**Relevant Industries:** Energy, Automobiles, Hydrogen Storage, Forklifts or Stationary Applications.

**Faculty:** Prof. Pratibha Sharma, Energy Science & Engineering.

## Biogas Enriching CO<sub>2</sub>/CH<sub>4</sub> Separation Membranes

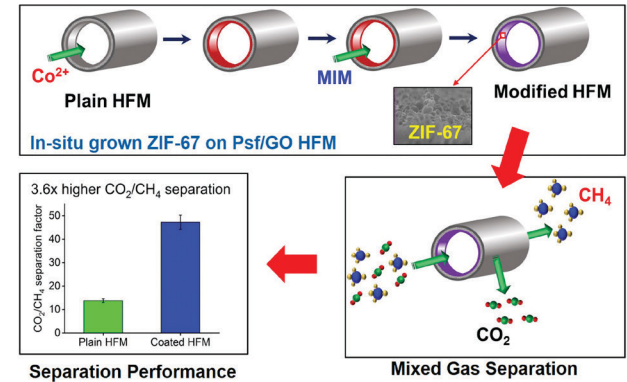
**Problem Statement:** As the demand for fossil fuels rises and its prices fluctuate, governments worldwide are exploring other alternatives, notably renewable energy sources. Thus, there is a need to identify and apply renewable energy sources for vehicles and domestic fuel; the potential of biogas can be tapped by removing the contaminant, CO<sub>2</sub>. The government of India has come up with a scheme, “Sustainable Alternative Towards Affordable Transportation (SATAT)”, which is an initiative aimed at setting up Compressed Bio-Gas production plants and making them available in the market for use in automotive fuels by inviting expression of interest from potential entrepreneurs. Recognising this need, researchers at IIT Bombay have devised a product to meet this need for enriching biogas by CO<sub>2</sub>.

**Uniqueness of the Solution:** The properties of membranes and zeolitic imidazolate frameworks-67 (ZIF-67) are combined to affect the CO<sub>2</sub> and CH<sub>4</sub>

separation. Here, hollow fibre membranes of polysulfone coated with ZIF-67 nanoparticles showed a mixed gas (with 50:50 mol% feed gas) CO<sub>2</sub>/CH<sub>4</sub> selectivity of  $44.94 \pm 3.00$ , and CO<sub>2</sub> permeance of  $39.25 \pm 2.30$  GPU was achieved. These results were obtained at 1 bar total pressure of feed gas.

**Current Status of Technology:** The experiments were conducted using 14 cm length of single fibres. The novel in-situ grown ZIF-67 on Psf/GO HFMs showed improved CO<sub>2</sub>/CH<sub>4</sub> separation performance, making these modified membranes potentially useful for practical gas separation applications. However, further experiments need to be carried out for a higher flow rate of feed and a large number of fibres in a module. The research has been published in a peer-reviewed journal.

**Societal Impact:** Biogas can be used as fuel for vehicles and domestic purposes. Biogas contains carbon dioxide, which



does not burn, in addition to the primary fuel gas methane, and carbon monoxide. Purifying biogas by removing carbon dioxide improves biogas efficiency. This technology can help society by reducing fuel costs.

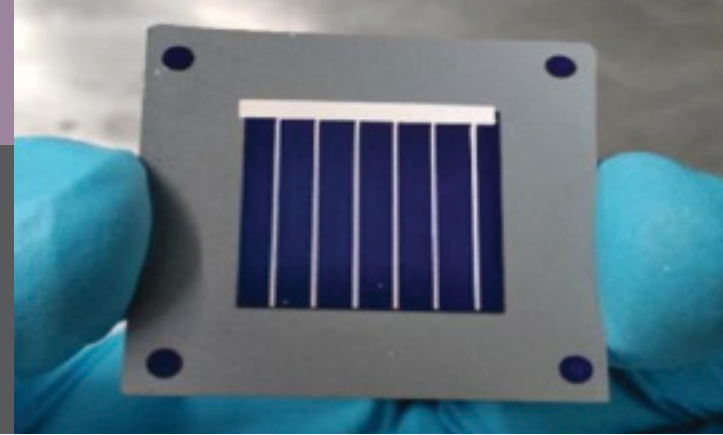
**Patent(s):** Nil

**Relevant Industries:** Clean Energy, Materials, Biogas Upgrading Industries.

**Faculty:** Prof. Jayesh Bellare, Chemical Engineering.



## Fabrication of Crystalline Silicon-Based Heterojunction (SHJ) Thin-Film Solar Cells



**Problem Statement:** Most solar panels that we come across today constitute low efficiency but commercially viable polycrystalline silicon solar cells. These cells are increasingly being replaced by high-efficiency monocrystalline PERC solar cells. However, the fabrication of these cells involves several photolithography steps, due to which their cost is high. Furthermore, the processing temperature of such solar cells also demands high temperatures and hence more energy requirements. Again, c-Si, a material with an indirect bandgap, has a low absorption coefficient due to which thicker wafers are used, which affects the final cost of the cell. The researchers have addressed these drawbacks by fabricating low-cost solar cells.

**Uniqueness of the Solution:** The development of an industry-friendly process for fabricating high efficiency c-Si solar cells based on the heterojunction with intrinsic thin film (HIT) concept is demonstrated. All the amorphous

silicon layers are deposited using the hot-wire chemical vapour deposition (HWCVD) technique. Employing low-temperature processing in developing heterojunction solar cells lowers not only the thermal budget but also material cost. Also, since cell fabrication does not incorporate sophisticated steps such as photolithography, its upscaling for industry integration will prove significantly easier.

**Current Status of Technology:** Single and double-sided SHJ solar cells have been fabricated (active area 2.3 cm<sup>2</sup>) and characterised in the laboratory under standard test conditions (STC) of 25°C operating temperature, 1.5 reference air mass.

**Societal Impact:** Availability of solar panels constituted by indigenously fabricated low-cost, high-efficiency cells increases application for rooftop energy generation, agricultural and irrigation demands, and transportation; it thereby

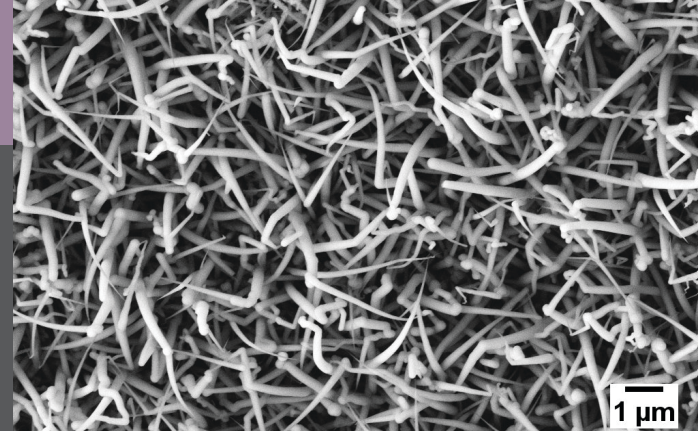
improves the quality of living, especially in rural areas where a continuous supply of electricity is still a challenge.

**Patent(s):** Nil

**Relevant Industries:** Energy, Renewables.

**Faculty:** Prof. Rajiv O. Dusane, Metallurgical Engineering and Materials Science.

## Growing Silicon Nanowires on Copper Substrate at Low Temperature



**Problem Statement:** The lithium-ion batteries have high energy density and are currently being used in Electric Vehicles (EVs) manufactured by Tesla, Maruti Suzuki, Ather Energy (Hero Moto Corp.), General Motors, Nissan, BMW and others. The researchers have designed silicon nanowires grown on copper foils that can be deployed as anode for lithium-ion batteries. The sodium-ion battery market is also on the rise, and these nanowires also find use as the anode in them. These silicon nanowires have tunable dimensions and morphology on copper substrates at low temperatures and can be used in applications like rechargeable lithium and sodium-ion batteries.

**Uniqueness of the Solution:** The bottom-up method of silicon nanowire growth allows fine-tuning the process parameters and thus the morphology and dimensions of silicon nanowires needed for a particular application. The growth through the unique hot wire

assisted vapour liquid-solid mechanism allows the growth on a variety of substrates including, but not limited to, copper, stainless steel, glass, etc. The nanowires grown through this method have a composite structure consisting of crystalline core amorphous shell structure in a one-step process. Further, the growth of these nanowires directly on copper foils makes it a convenient electrode material for batteries that do not require any further processing before going into the device structure.

**Current Status of Technology:** The researchers have successfully demonstrated the battery prototype at the lab scale. They have also validated by integrating it in a standard consumer electronic device (Casio fx-991MS calculator, 0.2 mW). Another successful demonstration of this prototype was lighting up an array of 61 red LEDs arranged to spell out 'IITB' for about 60 minutes.

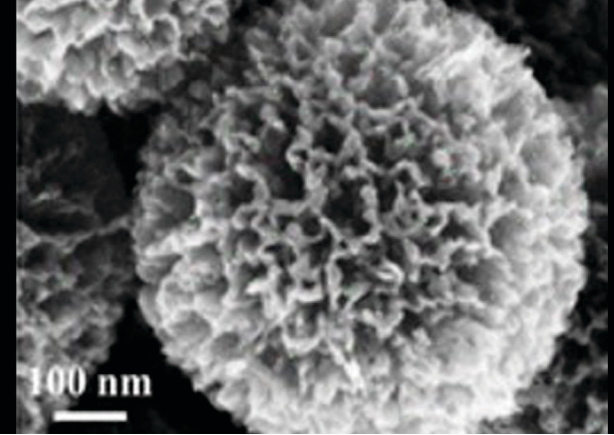
**Societal Impact:** The novel technology can be deployed as an anode in batteries used for EVs. Thus, this innovation can contribute to the betterment of society by providing clean energy for all and thus reducing the ill effects of climate change which are borne by the whole society.

**Patent(s):** under progress

**Relevant Industries:** Clean Energy, Renewables, Batteries, Supercapacitor.

**Faculty:** Prof. Rajiv O. Dusane and Prof. Amartya Mukhopadhyay, Metallurgical Engineering & Materials Science.

## Harnessing Sunlight to Heat Rooms and Clean Water



**Problem Statement:** Steam forms an essential part of energy conversion in nuclear and thermal power plants, medical sanitisation and water purification. While using non-renewable sources for producing steam involves a large carbon footprint and is becoming unsustainable, a greener alternative using solar energy suffers from a lower rate of steam production. Thus, there is a demand for processes and materials that can efficiently convert solar energy to thermal energy, which can subsequently be channelised for rapid steam generation from water and heating rooms or spaces.

### **Uniqueness of the Solution:**

Indigenously developed nanocarbon florets (NCF) are coated on various arbitrary surfaces (paper, cloth, clay, metal, glass) to achieve about 90% efficiency in converting solar energy to thermal energy. It was possible to generate a surface temperature of about 150°C upon illumination with 2000 W/m<sup>2</sup> of solar power. This heat energy has

been channelled to generate steam at a high rate of 5 kg/m<sup>2</sup>.h, the highest in the domain, without employing any solar concentrators. Using heat energy thus generated, the team also demonstrated effective bacterial removal of 99.9%, with the initial bacterial concentration of 106 CFU/ml, and green, sustainable space/room heating with a temperature difference of 25°C. The team has demonstrated several months of continuous usage for these three applications.

**Current Status of Technology:** After lab-scale experiments, the team has fabricated a prototype and has shown that it performs well on-field.

**Societal Impact:** The technology developed by the team can be used to set up the purification of water and space heating at a community level and industrial scale. It provides a new and socially-relevant direction for effective solar energy utilisation. The technology

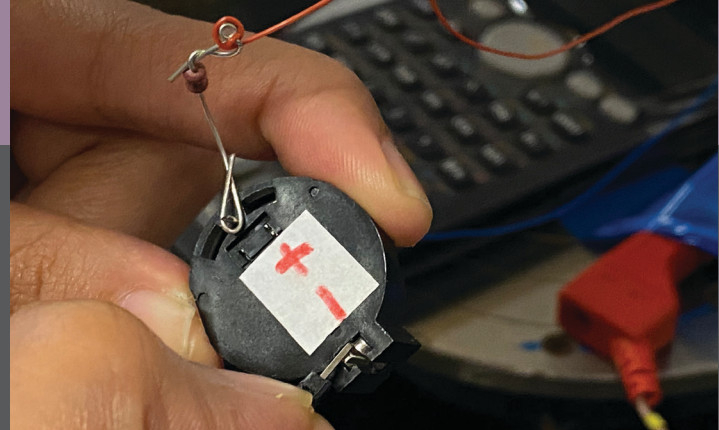
is helpful to realise non-polluting water purification, steam-based sanitisation in medical industries, and non-polluting space heating, especially in areas with abundant sunshine but low ambient temperatures.

**Patent(s):** Nil

**Relevant Industries:** Clean Energy, Water.

**Faculty:** Prof. Sandip Saha, Mechanical Engineering and Prof. Chandramouli Subramaniam, Chemistry.

## High-Performance, Sustainable and Cost-Effective Na-Ion Battery Systems



**Problem Statement:** Renewable energy sources and electric vehicles are crucial to address fossil fuel depletion and environmental pollution. However, renewable resources are intermittent, making simultaneous development-cum-deployment of energy storage technologies mandatory. Therefore, it is essential to develop cost-effective, resource-friendly, safe, and sustainable alkali metal-ion battery systems beyond Li-ion battery systems. India lacks Li-sources but has abundant Na-sources, so the upcoming Na-ion systems set to replace/supplement Li-ion systems is important for India. Currently, commercial competition for Na-ion systems is less than Li-ion systems but may not remain so in a few years. The proposed system aims to develop 'full' Na-ion battery systems that have a combination of desired characteristics, such as high rate-capability, cost-effectiveness and environmental/health friendliness needed for heavy-duty applications as in electric vehicles.

**Uniqueness of the Solution:** The to-be-developed Na-ion battery systems will have energy and power density and safety aspects superior to the state-of-the-art systems, most of which are at the research stage. Research from this team has shown that, unlike the current commercial Na-ion battery systems, it is possible to have 'aqueous processed' electrodes because the as-developed cathode and anode materials are water-stable, allowing the use of water and water-based binders for preparing electrodes. Since the usual electrode materials are hygroscopic, they are prepared using highly toxic, hazardous and expensive chemicals such as N Methyl Pyrrolidone (NMP) and Polyvinylidene fluoride (PVDF). As an important research outcome, the use of water-stable materials will lead to the development of health/environment-friendly, cost-effective and sustainable Na-ion battery systems.

**Current Status of Technology:** Prototypes being developed in collaboration with some companies

**Societal Impact:** Cost-effective electrochemical energy storage systems significantly reduce the dependence on fossil fuels and improve the quality, flexibility and health of human life worldwide due to the use of renewable energy sources.

**Patent(s):** Nil

**Relevant Industries:** Batteries, Clean Energy, Renewables.

**Faculty:** Prof. Amartya Mukhopadhyay, Metallurgical Engineering and Materials Science.

## Lightweight Fuel Cell Stacks for Light-Duty Vehicles

**Problem Statement:** Conventional IC engine based powertrain causes carbon dioxide emissions and air pollution. Vehicle drive trains need to be replaced by alternatives. A fuel cell is a major contender to replace existing fossil fuel dependency. A fuel cell vehicle uses an electric traction system coupled to a single-speed drive, powered with a Li-Ion Battery or a supercapacitor and a PEM-based Fuel Cell power system, instead of an IC engine. An electric powertrain requires an energy system with high volumetric and gravimetric energy and power density. The prime objective of the present work is to develop an electric drive train suitable for light-duty vehicles based on compressed hydrogen storage and fuel cells.

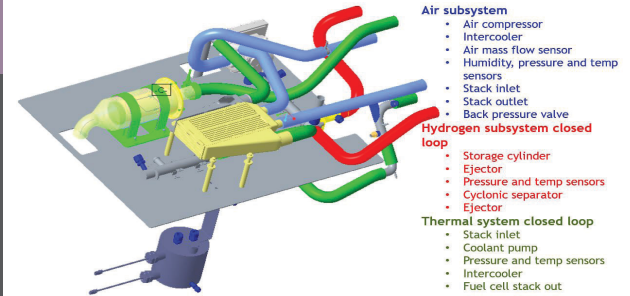
### Uniqueness of the Solution:

Conventional graphite plates used in fuel cells have the limitation of high gravimetric and volumetric power density. In the present work, the team has replaced the graphite bipolar plate

with a lightweight metallic bipolar plate which substantially reduces the weight and volume of the fuel cell system. They have designed a metallic bipolar and developed a lightweight fuel cell stack suitable for automobile applications. They have also developed a Balance of Plant (BoP) for the fuel cell stack, suitable for light-duty vehicles. They have explored a lightweight gas distribution system to achieve desired gravimetric and volumetric power density. The flow field design is also crucial for performance. The optimum flow field will be designed to minimise water flooding and improve the current density distribution.

### Current Status of Technology:

The technology is ready with all the components required for the fuel cell stack, tested in the laboratory. The subsystem necessary for the fuel cell and the BoP is completed. The team is in the process of finding an electric vehicle to retrofit their system.



**Societal Impact:** Green hydrogen is expected to be one of the few areas India has recently taken steps to keep itself at par with global technology leaders. Fuel cells are considered as potential alternatives for future green mobility.

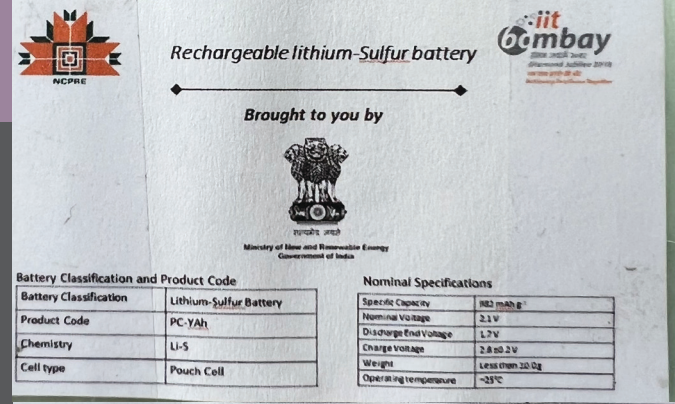
**Patent(s):** In Process

**Relevant Industries:** Clean Energy, Renewables, Automotives, Metals.

**Faculty:** Prof. Prakash C Ghosh, Energy Science & Engineering.



## Lithium Sulphur Battery Development



**Problem Statement:** Lithium-sulphur batteries are considered one of the most promising alternatives to commercial lithium-ion batteries due to their high theoretical energy density (2600 Wh/kg). However, due to sluggish reactions between sulphur and lithium, Li-S batteries have poor practical capacity. Active material and the intermediate product gradually dissolve into the liquid electrolyte, so Li-S batteries lack cycling stability. Unprotected lithium anodes show parasitic reactions with the electrolytes and suffer from uncontrollable lithium dendrite growth upon repeated lithium plating and stripping. The success of the lithium-sulphur (Li-S) batteries largely relies on the direct utilisation of elemental sulphur as a cathode with protected metallic lithium as the anode.

**Uniqueness of the Solution:** The lithium-sulphur rechargeable batteries developed by the IIT Bombay team uses sulphur powder directly, a cost-effective way to prepare cathode material.

It uses a thin layer of lithium as the anode. It is safe despite using lithium. It can be used in lower temperatures (lower than 5°C) without much thermal management. Except for lithium, all materials are available in India, reducing the dependency on imports. The battery offers about thrice the power density than the current lithium batteries at the same power output. Cathode preparation is facile and cost-effective; the battery shows stable cycling performance and adequate practical cell capacity. The technology is scalable to bulk production of Li-S batteries.

**Current Status of Technology:** Lab-scale cell fabrication and coin cell testing are completed. Currently, two-layer pouch fabrication and testing are going on.

**Societal Impact:** Li-S battery uses sulphur as an active cathode, eliminating the dependency on elements like cobalt and Nickel. The energy density Li-S battery is 2-3 times higher than a

commercial lithium-ion battery, reducing the distance anxiety of electric vehicles. Indigenous technology will save time and cost for local production. Workforce training in new technology will benefit India.

**Patent(s):** Filed

**Relevant Industries:** Batteries, Clean Energy, Renewables.

**Faculty:** Prof. Sagar Mitra, Energy Science & Engineering.

## Lithium-Ion and Sodium-Ion Battery Prototyping at IIT Bombay



**Problem Statement:** Barring a few organisations, the knowledge of battery cell technology and how to manufacture them is largely lacking in Indian organisations, including the IITs. India needs to be self-reliant in developing and manufacturing energy storage technologies that meet the unique requirements of the electric mobility and renewable energy sectors.

**Uniqueness of the Solution:** The current project team at IIT B-Monash Research Academy is the first to make a world-class facility to fabricate batteries in the IIT ecosystem. The Battery Prototyping Lab is a unique facility that will help bridge the gap between industry and academia by facilitating the prototyping and scaling up of energy storage technologies researched and developed in the institute. The lab has a full prototyping capacity of 4 kWh per day in the format of 10Ah pouch cells of 1kWh per day in the format of 2.5 Ah 18650 cylindrical cells. The team is working on

prototyping advanced anode-free, ultra-fast, ultra-safe battery technology for EVs and long cycle life battery technology based on Li-ion and Na-ion. They are developing Si-C and NMC/LFP chemistry for more than 280 Wh/kg battery. They are conducting trials on the advancement of known cathodes such as LCO, LMO, NCA, NNMC for their long cycle life and fast charge capability.

**Current Status of Technology:** All prototype Li-ion cells are tested in the field. They are ready to be used in pilot-scale production. Indigenous Na-ion battery technology and cell development are in progress with Industry partners. 220 Wh/kg cell chemistry and 10 Ah pouch cell development are under process with collaboration for Indian industry partners.

**Societal Impact:** Indigenous cell technology and know-how are essential to grow and support India's EV program. The IITB-Monash Research Academy's workforce training and support for cell

manufacturing, cell testing and analysis can help meet the ever-increasing demand for technical know-how and help the industry make battery cells.

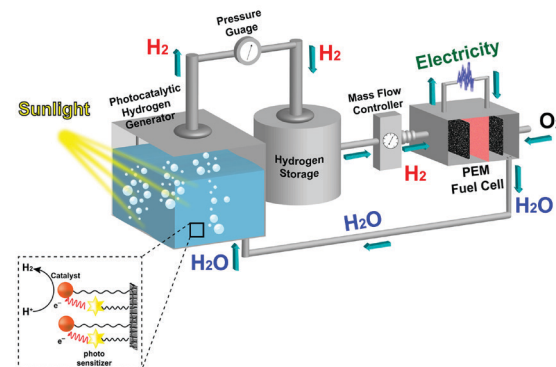
**Patent(s):** Filed.

**Relevant Industries:** Batteries, Energy Storage.

**Faculty:** Prof. Sagar Mitra, Energy Science & Engineering.



## Natural Sunlight-Driven H<sub>2</sub> Generation from Water



**Problem Statement:** Using hydrogen as a fuel emerged as one of the possible avenues for minimising carbon dioxide emissions due to burning fossil fuels. The direct storage of readily available solar energy into an H-H bond (chemical form) is a key step for an H<sub>2</sub>-driven power generation methodology. An efficient, sustainable, and scalable water to H<sub>2</sub> production technology that can enable a carbon-neutral energy infrastructure is missing. Currently, no product for direct H<sub>2</sub> production from solar irradiation is available in the Indian market. The solar to electricity converters and electrolyzers are available separately; however, their combination doesn't provide an energy-efficient and readily-usable solution.

**Uniqueness of the Solution:** The team aims to construct a prototype of a sustainable hydrogen-gas-(H<sub>2</sub>)-generator that can be directly linked with a fuel cell for regulated electricity production. The H<sub>2</sub> generator will be functional in neutral water with solar irradiation under the

most practical conditions (temperature 15-80°C, in the presence of aerial oxygen, without the usage of any hazardous organic solvents or acids).

**Current Status of Technology:** The team has established the proof of concept and validated the assembled components in the laboratory environment.

**Societal Impact:** The proposed sunlight-driven electricity generator is environmentally friendly as it produces water as the only by-product. It is energy efficient because it converts solar energy into an intermediate chemical vector (H<sub>2</sub> gas) which can be transformed into electricity as needed. This reaction pathway improves energy efficiency and regulation in solar to electricity production compared to conventional solar cells with no storable intermediates. It will also be economical since it will utilise an earth-abundant transition element as the H<sub>2</sub> production catalyst and biodegradable components. Also, the

final product of the process, water, will be recycled back to the photocatalytic H<sub>2</sub> generator unit, making electricity generation cheaper than the conventional solar-panel systems.

**Patent(s):** Nil

**Relevant Industries:** Power & Energy sector, Petroleum and Chemical industries.

**Faculty:** Prof. Arnab Dutta and Prof. Debabrata Maiti, Chemistry; Prof. Vikram Vishal, Earth Sciences.

## Rapid, Low-Cost Hydrogen Production Using Magnets

**Problem Statement:** Electrolysis of water has been a significant contender for the sustainable production of green hydrogen. However, the demand to enhance the energy efficiency of the electrolysis and minimise the use of expensive catalysts without affecting the rate of hydrogen production is gaining increased relevance, especially with India announcing the National green hydrogen initiative. Thus, the holy grail of achieving green hydrogen through electrolysis lies in achieving a high hydrogen production rate at lower energy and material costs, which the team envisages.

**Uniqueness of the Solution:** The solution demonstrated at the lab scale involves two significant innovations: introducing a weak external magnetic field (<500 mT, typical of a fridge magnet) to the electrolytic chamber; and the use of earth-abundant metal oxides (cobalt, nickel and their combinations) supported on a nanostructured hard-carbon matrix as a catalyst. These

innovations synergistically combine to decrease energy consumption by 20% and increase the hydrogen production rate by three times. Based on this, the cost of hydrogen produced using this technology would reduce to INR 250/kg, compared to the current INR 500/kg cost for electrolytic hydrogen. Further, it is expected to become cost-competitive with hydrogen from steam-reforming (INR 150/kg) with large-scale adaptability and commercialisation.

**Current Status of Technology:** The team has successfully demonstrated a lab-scale proof of concept and now solicits support from the industry for prototyping and commercial validation.

**Societal Impact:** This technology can make India a leader in green hydrogen production. It is expected to be of significant interest for steel industries that mainly utilise hydrogen from polluting, non-renewable sources.



**Patent(s):** Filed

**Relevant Industries:** Hydrogen Storage, Electric Vehicles, Clean Energy, Renewables.

**Faculty:** Prof. Chandramouli Subramaniam, Chemistry.

## Rechargeable metal-air batteries

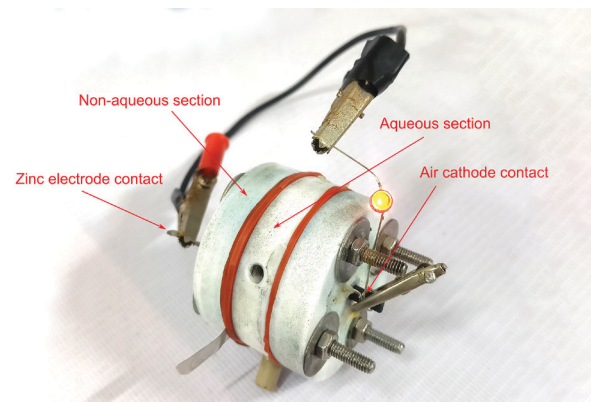
**Problem Statement:** Batteries are a missing link in the process of transitioning to renewable electricity. Rechargeable metal-air batteries can deliver a much higher capacity than the current batteries with Li-ion chemistry. However, metal-air batteries suffer from specific problems while achieving electrical rechargeability. The issues are mainly related to the reversibility of both the metal electrode and the air electrode reactions. The current invention aims to bypass the problems by applying a hybrid electrolyte design to ensure good reversibility at both the metal and the air electrode.

**Uniqueness of the Solution:** The current design completely decouples the reactions at the metal electrode and the air electrode using a third redox couple, making it possible to use an aqueous electrolyte at the air electrode while maintaining an aprotic environment at the metal electrode. The current invention aims to improve the rechargeability of metal-air batteries and therefore open a

possibility of their practical use for both portable and stationary applications.

**Current Status of Technology:** The team has fabricated a small cell and has performed charge-discharge experiments in a lab environment. They also fabricated a lab-scale prototype based on CuHCF as the auxiliary electrode material. A non-aqueous electrolyte is used for the metal electrode, and an aqueous electrolyte is used for the air electrode.

**Societal Impact:** Batteries are going to play a vital role in a power grid based completely on renewable resources. The current invention enables high voltage metal-air batteries as an electricity storage solution. Furthermore, the technology can be extended to several metal-air systems, including Na-air or K-air batteries.



**Patent(s):** Filed

**Relevant Industries:** Batteries, Clean Energy, Renewables.

**Faculty:** Prof. Arindam Sarkar, Chemical Engineering.

**Communication Technologies (including education and 5G)**

## Indigenous 5G Packet Core



**Problem Statement:** There is a need to develop an indigenous 5G core network that can be used as a proof-of-concept for future commercial implementations and a prototype to test future research ideas. India needs to have an indigenous 5G solution for many reasons, but an indigenously developed 5G core is critical given the security implications. Having an Indian, secure 5G core will be especially important for networks like defence and police.

**Uniqueness of the Solution:** Currently, any commercial grade 5G core network implementation that Indian academia or industry can use does not exist or is not available at a reasonable price. With their collaborators, the team has developed a solution that is part of and fully integrated with the larger end-to-end indigenous 5G/5Gi network. The solution is fully standards-compliant and has been tested with third-party components for interoperability. The 5G core components follow a cloud-native, high performance,

scalable design and follow all other industry best practices.

**Current Status of Technology:** All components were tested and validated with third-party testing equipment. The 5G core network is integrated with the rest of the 5G components and will be ready for a campus deployment soon.

**Societal Impact:** The solution proposed by the team can be a starting point for indigenously developed 5G products in India by Indian companies and startups. Having indigenously developed telecom products will lead to a maturation of the product ecosystem in India and help India climb up the ladder from being a technology consumer to a producer. In addition, developing Indian solutions to 5G will enable focusing on India-specific problems and push the nation's ideas into future standards.

**Patent(s):** Nil

**Relevant Industries:** Telecom, ICT.

**Faculty:** Prof. Mythili Vutukuru, Computer Science & Engineering.

## Programmable Virtual Communication Hub: Pro-H 1000



**Problem Statement:** This robust portfolio of programmable routing platforms from the Pro-H X000 series provides industry-leading system capacity, port density, security, and performance.

### Uniqueness of the Solution:

- Layer 0 - Layer 4 communication equipment
- Full carrier-grade features for data plane and OAM&P for control plane
- Software-Defined Networking using IIT Bombay's mega label multi-pipelined engine
- Benchmarked for low latency, low power consumption and long-distance ranges
- 50 ms restoration across all layers/ all services
- 1 Gbps, 10 Gbps, 100 Gbps ports; IPv6 compatible, MPLS supporting, MPLS-TP
- BGPv4 compliant
- A unique cloud NMS for worldwide control of your network
- Network analytics embedded in the

### NMS

- Sub 150 W power consumption and hot-swappable dual power supply
- Sub 10 microsecond port-to-port latency across IPv6
- 1 million addresses, route reflectors, router adjusters for IPv6
- Programmable pipeline to support a combination of Carrier Ethernet, IPv4, IPv6, MPLS, MPLS-TP
- SDN capabilities - flexible to customise scripts for use cases such as bandwidth calendaring, packet analytics, security group creation
- Compatible with third-party applications for implementing SDN
- Zero-touch provisioning - full automation of configuration and management

**Current Status of Technology:** Pro-H 1000 is a flexible, full-featured 1RU device that provides 360 Gbps full-duplex network bandwidth with 100 Gbps and 10 Gbps and 1 Gbps ports.

**Societal Impact:** Pro H 1000 SDN router is a paradigm shift in routing and switching and is key to digital transformation for service providers, cloud operators and enterprises.

**Patent(s):** Nil

**Relevant Industries:** Telecom, Defence, Security

**Faculty:** Prof. Ashwin Gumaste, Computer Science & Engineering.

# Defence and Aerospace



## High-Frequency X-Ray Power Source

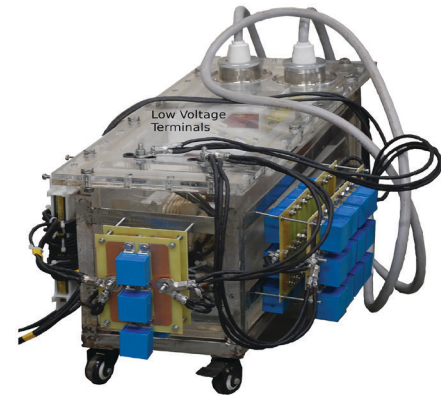
**Problem Statement:** The X-ray units manufactured in India rely on imported components. Hence the process of manufacturing them ends up being an assembly process. Only selected manufacturers around the globe make the power source required for X-Ray units. The current project entails developing a power source from the conceptualisation to the testing phase and eventual preparation for production, thereby increasing X-ray power sources available in India. These X-ray power sources can also be leveraged for use in the industrial sector for electrostatic precipitators, as well as high-frequency arc generation. Industrial requirements for DC fast chargers with EVs can also be addressed with the development. The project's genesis is rooted in industry interactions and requirements provided by the medical equipment manufacturers in India.

**Uniqueness of the Solution:** The solution proposed by the team is one-of-its-kind with respect to a combination of high

voltage and high-frequency outputs. The multi-functional design can be easily customised and scaled for different industrial and defence applications. This solution can compete with the medical segment products manufactured by leading multinational companies like Spellman, X-Power, Siemens, and Philips.

**Current Status of Technology:** The current project is in the component and/or breadboard validation stage in the relevant environment.

**Societal Impact:** Developing a high-frequency X-ray power source can help provide effective solutions at a reasonable cost and aid in establishing medical facilities in the primary healthcare sector. The possibilities for customisation allows for providing solutions to varied sectors, especially pollution reduction, environment and clean energy, and transportation. The market potential for the technology is significant.



**Patent(s):** Under progress

**Relevant Industries:** Biomedical Engineering, Defence, Security, Manufacturing, Power Plants, Refineries, Medical Equipment Manufacturers.

**Faculty:** Prof. Himanshu Bahirat and Prof. Mukul Chandorkar, Electrical Engineering.

## NETRA: Naval Equipment and Task Reliability Analyzer Software

**Problem Statement:** All asset-intensive organisations require reliability prediction, health monitoring, residual life prediction, and maintenance optimisation of their assets. The researchers have addressed this requirement by developing a mission, task and equipment reliability prediction and analysis software, aptly named NETRA (Sanskrit for an eye), for Indian Navy ships. NETRA stands for Naval Equipment and Task Reliability Analyzer. It can bring down the human resource cost for the organisations depending on the required features of the NETRA software.

**Uniqueness of the Solution:** There is no similar solution (equipment reliability software) available in the market. The software is configurable for other asset-intensive organisations like the Indian Army and Coast Guards. To a large extent, this software automates the reliability model creation, and it can be integrated with existing CMMS (Computerised Maintenance Management System) and sensor-based

data acquisition systems. The various modules incorporated within NETRA are reliability prediction, reliability centred maintenance recommendation, condition monitoring of assets, residual life (time to next failure) estimation and maintenance optimisation. NETRA software is a cost-effective solution as it can reduce some human resource costs.

**Current Status of Technology:** The researchers have completed one out of the four stages. They plan to deliver the entire software in the next one and a half years.

**Societal Impact:** The product is mainly developed for defence and other asset-intensive organisations like the army, coast guards, railways, mining and petrochemical industry, power generation industry and manufacturing plants. It can significantly help in their asset and equipment management process.

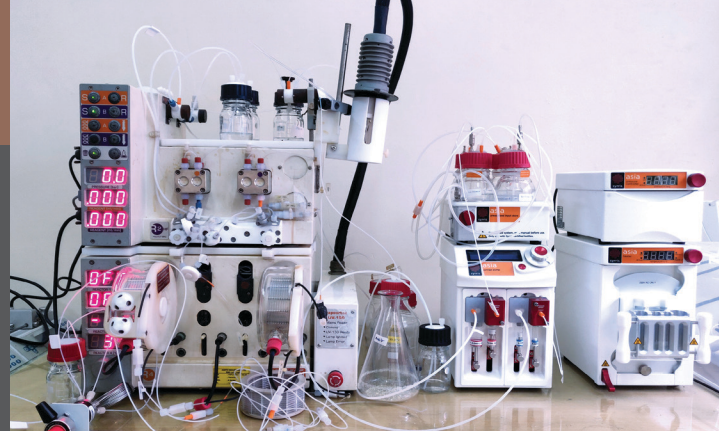
**Patent(s):** In progress

**Relevant Industries:** Defence, Aerospace, Mining, Petrochemicals, Power, Manufacturing, Railways.

**Faculty:** Prof. Makarand. S. Kulkarni, Mechanical Engineering.



## Scalable High Energy Materials (HEM) Synthesis



**Problem Statement:** High Energetic Materials (HEM) synthesis is difficult to scale up in batch due to their high reactivity. They are generally sensitive to heat, mechanical shock, and spark. They can explode during their synthesis if prepared on a bulk scale. The general batch synthetic procedures are of longer duration and a mixture of product forms. Currently, defence and other organisations in India do not synthesise high nitrogen energetic materials using continuous flow. The researchers have proposed a continuous flow methodology to address this requirement and produce different high nitrogen energetic materials on a bulk scale in a safer manner, which will strengthen the indigenous defence capability.

**Uniqueness of the Solution:** The researchers have developed a methodology using continuous flow reactors, where the reaction will occur in micro-channels providing better heat and mass transfer among the molecules

giving a short reaction time. It can support on-demand production. Fully optimised flow reactor methodology is used to scale up and prepare the high nitrogen compounds on a kilogram scale, unlike batch processes. The use of tabletop models can replace the bigger asset requirements, thus reducing the plant footprint.

**Current Status of Technology:** The researchers have designed a prototype assembling flow reactors and successfully synthesising high nitrogen-containing molecules such as 2,4-dinitroanisole (DNAN, secondary explosive) and cyanuric triazide (CTA, Primary explosive). Both of these molecules can be produced in gram to kilogram scale in a safer manner under industry-relevant conditions.

**Societal Impact:** The proposed methodology eliminates hazards and increases process safety. This technology can be utilised by DRDO,

ISRO, Naval Research, Premier Explosive Limited, Economic Explosive Limited and other defence-related organisations to strengthen our national security.

**Patent(s):** Under progress

**Relevant Industries:** Defence, Aerospace, Energy, Chemicals.

**Faculty:** Prof. Debabrata Maiti and Prof. Arnab Dutta, Chemistry.

# Smart Drone and Integrated Mobility Systems



**Problem Statement:** Drones find use in precision agriculture, smart delivery systems, connected systems for automated public safety, as well as tracking and surveying for military and cyber security applications. They are the need of the hour. AI-based attacking/battle/police drones and internet-centric operation (internet of battle things) and various air, ground and sea services like air taxis and flying cars are also gaining importance. However, currently, no smart integrated drone ecosystem exists in India. The researchers are developing a drone-based ecosystem that can be used in social, industrial, commercial, security and defence applications. They are addressing the need for a sustainable and intelligent automated ecosystem for smart, secured and safe drones in integrated and interconnected mobility systems to solve critical and high-risk problems and high-impact projects.

**Uniqueness of the Solution:** The researchers are working to develop

an entire drone-based, sustainable ecosystem in India for smart and trustworthy drones for use in integrated mobility systems. The ecosystem will intelligently interconnect various drones, other mobility systems, people, processes, and data.

**Current Status of Technology:**

The various subsystems within this ecosystem are currently in various stages of development (TRL 1 to 5), including prototype development, testing completed in the laboratory, and field testing in relevant environments.

**Societal Impact:** Drone ecosystems have a variety of applications in defence, agriculture, delivery, public safety, disaster management, and emergency service applications, all of which have widespread societal impact. They also encourage entrepreneurship, societal welfare resulting in economic growth and employment generation.

**Patent(s):** Nil

**Relevant Industries:** Defence, Smart Mobility, Aerospace, Security.

**Faculty:** Prof. Arnab Maity, Prof. Hemendra Arya, Prof. Chandra Sekher Yerramalli, Aerospace Engineering; Prof. Leena Vachhani, Prof. Arpita Sinha, Systems & Control Engineering; Prof. Gaurav Kasbekar, Electrical Engineering and Prof. Anirban Guha, Mechanical Engineering.

**Environment and Sustainability (including air, water, rivers)**

## Daksh: A Household-cum-Community Scale Composter

**Problem Statement:** With the increase of garbage in the streets, pollution, foul odour, poor waste disposal sites and related health problems, solid waste management (SWM) is affecting every person in the country. Irrespective of many public and government initiatives, SWM efforts have remained the same for years. In India, solid waste still ends up in dumping grounds without treatment; hence there is a need to divert the waste from landfills by appropriate methods. Sustainable Waste-to-Energy requires the sophisticated collection, segregation and transportation. Home composting offers potential towards zero waste management, with an easy-to-use decentralised approach. The present research explores developing a composter for communities offering daily storage and composting.

**Uniqueness of the Solution:** Current composting products available in the market are not optimised to induce rapid composting in minimum available space.

The research team proposes a product that will offer an economical design that can support optimum environmental conditions for the biodegradation of household organics. The product offers daily storage of waste and composting, with a provision for compost storage and leachate collection. The unit cost is estimated at around INR 3500-7000 for four families, each having four members.

**Current Status of Technology:** The product is under the prototype and testing stage. Initial studies on household-cum-community scale composters have been performed, and the design parameters of the reactor are studied.

**Societal Impact:** The reactor household-cum-community scale composter helps reduce stress on landfills, and is in line with Swachh Bharat Abhiyaan. The involvement of the public in participation in waste reduction creates maximum awareness on the reuse of kitchen waste in the form of compost. The end



product increases greenery, afforestation, urban landscaping, green terraces, zero waste management, and solid waste management.

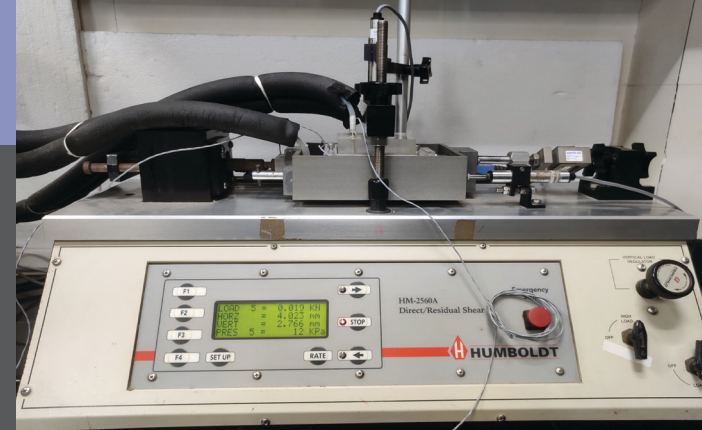
**Patent(s):** Nil

**Relevant Industries:** Household, Housing Societies, Cities and Urban Local Bodies.

**Faculty:** Prof. Anil Kumar Dikshit, Environmental Science & Engineering.



## DetFroSS: Frozen Soil Shear Strength Estimator



**Problem Statement:** India showcases a wide range of soil types at varying altitudes and temperatures. Knowledge of these environmental circumstances is necessary for an ecologist and an engineer to know how, why, and what kind of materials should be utilised to construct hefty buildings on soil in different temperature zones. Understanding aspects like the soil's shear strength, density, saturation and dryness/moisture are essential in designing the foundation for structures in cold regions of India. DetFroSS is a setup designed to determine the shear strength of the frozen soil corresponding to different temperatures (ranging between 0°C - 25°C).

**Uniqueness of the Solution:** The proposed invention of developing Frozen Soil Shear Strength Estimator enables the determination of shear strength of frozen soil mass quickly and economically compared to the ones existing in previous literature. Also, volumetric deformation, a crucial aspect of soil, is essential to

analyse as the deformation could be due to mechanical loading or environmental changes. However, if not analysed, it might impact the foundation during construction. Therefore, the estimator determines the volumetric deformation undergone by the soil sample in its fully or partially saturated states, compacted to a target dry-density and subjected to different confining pressures.

**Current Status of Technology:** The team of researchers have set up the strength estimator. It is ready to use to determine the soil characteristics economically and rapidly in regions with a soil temperature of up to 25°C, such as in areas like the Northeast part of India.

**Societal Impact:** This test setup to determine the shear strength of frozen soil in the cold regions in India will be helpful in the execution of infrastructure development, mainly in the Northeast states in India.

**Patent(s):** Filed

**Relevant Industries:** Infrastructure, Laboratory Material Testing Equipment Manufacturers.

**Faculty:** Prof. D. N. Singh, Civil Engineering.



## Drones for More Crop per Drop



**Problem Statement:** Indian farmers depend largely on traditional agricultural practices and ancestral knowledge of farming. However, there are a few challenges to pursuing agriculture considering climate change (acid rain, temperature fluctuations, precipitations) aspects. On the other hand, implementing technology and its knowledge regarding overall farming (like proper watering, use of fertilisers, or pesticides) and timely harvesting of healthy crop yields need to be resolved in today's farming. For these operational efficiencies, the digital revolution in agriculture is the need of the hour. This project is a stepping stone towards using technology by small and large-scale farmers; By utilising this technology, they will be able to decide when, where, what, and how many inputs of resources they need for healthy farming practises.

**Uniqueness of the Solution:** The present technique uses science-based and machine-learning approaches on

pure-pixel hyperspectral data to create models that can run on low computational power machines. The models can create plant-level stress maps. Farmers can distinguish between crop water and nitrogen stress using remotely sensed hyperspectral data as a solution for healthy farming.

**Current Status of Technology:** The models are validated a couple of times on the research front and ready to be used by the production team to make it a viable decision support system software for farmers.

**Societal Impact:** The technique will help reduce groundwater pollution by minimising the nitrate-nitrogen losses from agricultural land. Using this method achieves a huge reduction in soil pollution, especially soil heavy metals and the amount of fertilisers. The optimal use of chemicals in the farm and the food grains help to manage the food safety standards through reduced health risk

issues to the farmers and consumers. Maintaining food security through optimal use of fertilisers helps achieve optimal yield without damaging soil fertility in the long run.

**Patent(s):** Nil

**Relevant Industries:** Agriculture, Sensors, Water, Remote sensing, Spectroscopy.

**Faculty:** Prof. J. Adinarayana, Centre for Studies in Resource Engineering.

## Green Sewage Treatment Plant Based on Integrated Wetland Technology



**Problem Statement:** Conventional Sewage Treatment Plant (STP), unlike the usual sewage treatment process, follows an activated sludge process to biodegrade and remove pollutants from wastewater to reuse the recycled water. The process requires huge capital for construction and extensive power, machinery and skilled labour for operation, and heavy maintenance expenses. The efficiency and aesthetics of the STPs are also affected by various factors like the odour from the hydrogen sulphide and a whiff of ammonia; solid sludge dumping in the premises of the treatment plant; local climate factors, appropriate sewage volume and sewage characteristics that enter the STPs. Thus, we need alternative solutions.

**Uniqueness of the Solution:** The system makes use of natural treatment of sewage water via microbes and plant-based ecology.

**Current Status of technology:** The

green Sewage Treatment Plant (gSTP) system has gone through various stages of testing, and several systems have been successfully implemented across Maharashtra. Soon, the team will install one gSTP system at the WALMI campus in Bhopal and another at the Central Railway Bodybunder Depot in Mumbai.

**Societal Impact:** The increase in ecological awareness and new regulations in wastewater treatments has questioned conventional wastewater treatment methods about the use of hazardous chemicals during the degradation of the sludge, dumping of solid sludge waste, and maintaining cleanliness in the STPs. The gSTP system is innovative, reduces energy-related costs, provides a better and cheaper alternative for sewage treatment as the degradation process is natural using aerobic and anaerobic microbes. And the solids, instead of dumping in the premises, are utilised and absorbed by the plants. The technology in gSTPs reduces the contamination of

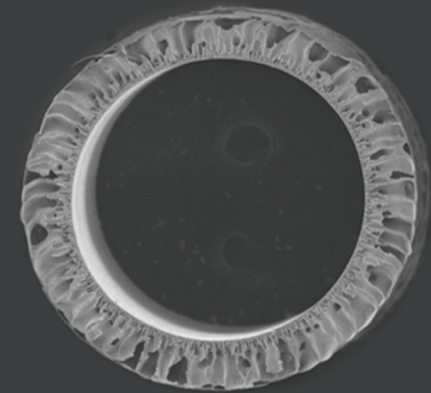
natural wetlands and other water bodies. This process also reduces our reliance on conventional STPs.

**Patent(s):** Nil

**Relevant Industries:** Municipalities, Cities, Towns, Environment.

**Faculty:** Prof. Anil Kumar Dikshit, Environmental Science & Engineering.

## High Flux Anti-fouling HFM for Water Treatment Application



**Problem Statement:** In wastewater treatment, several biomedical applications and instances that involve separation, membrane technology is widely used. However, one of the major technical challenges is fouling. Fouling is characterised by the adsorption of particles or compounds on the surface or the blocking of pores by particles during the filtration process. Fouling of membrane reduces its efficiency, durability, and increases operational cost. It significantly affects membrane performance by reducing flux membrane durability and rising operating costs due to the cleaning of membranes. Thus, fouling-resistant hollow fibre membranes (HFMs) development is an emerging research area. Taking on this challenge, researchers at IIT Bombay have devised a high flux anti-fouling HFM for water treatment applications.

**Uniqueness of the Solution:** The blending of hydrophilic additives in polyethersulfone to enhance antifouling

property and durability of hollow fibre membranes is a unique feature. The researchers have used carboxylated multi-walled carbon nanotubes (MWCNTs-COOH) that were embedded in hollow fibre membranes (HFMs). This was developed by blending polyethersulfone (PES) and d- $\alpha$ -tocopheryl polyethylene glycol 1000 succinate (TPGS, a vitamin E derivative) to remarkably enhance their permeation flux and fouling-resistance. The antifouling performance of HFMs was examined by calculating the change in pure water permeability (PWP) due to fouling by protein and synthetic municipal wastewater (SMWW). The novel PES composite HFMs containing TPGS and MWCNTs-COOH have shown excellent antifouling properties, which makes them potentially useful for wastewater treatment.

**Current Status of technology:** The module, high flux anti-fouling HFM for water treatment applications, has been tested at a lab-scale and will be scaled up

to the pilot plant.

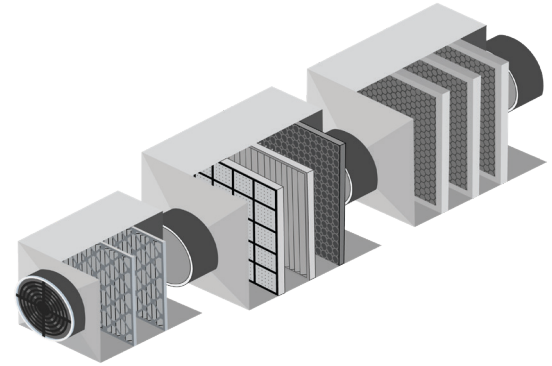
**Societal Impact:** The proposed module is a low-cost solution for filtration of domestic wastewater to provide water for non-drinking applications.

**Patent(s):** Filed

**Relevant Industries:** Environment, Water Treatment, Effluent Treatment Plants, Materials.

**Faculty:** Prof. Jayesh Bellare, Chemical Engineering.

## Indoor Air Quality Control Technology for Parking Lot



**Problem Statement:** Increasing concentrations of exhaust emissions from motor vehicles, especially in the enclosed/ insufficiently ventilated environment, are detrimental to human health and cause long-lasting ill effects. Due to space constraints in metro and smaller cities, multi-level parking has become a popular choice in public and residential societies. However, most multi-level parking lots are enclosed areas with inadequate/negligible ventilation, obstructing the free airflow, resulting in toxic air pollutants in the vicinity. Hence, it is necessary to curb these toxic air pollutants in parking lots.

**Uniqueness of the Solution:** Not many technologies are available to curb the air pollutants from parking lots. The product design is specifically suited to filter and purify air pollutants such as carbon monoxide (CO), hydrocarbons (HC), volatile organic compounds (VOCs), nitrogen oxides (NO<sub>x</sub>) and particulate matter (PM) released from motor vehicles.

The proposed Indoor air quality control technology is a unique air filtration unit based on the principle of three units: Filtration unit (for PM removal); Thermal Catalytic Oxidation (TCO) unit for removal of CO, VOC and HC; and Selective Catalytic Reduction (SCR) unit for NO<sub>x</sub>. Based on the type of pollutant to be removed, a combination of units is placed in series.

**Current Status of Technology:** The Indoor Air Quality Control Technology is in the prototype stage and is undergoing testing. Installation of pollution abatement devices in the parking lots requires precise mathematical modelling simulation of the system and best-fit technology selection which this technology addresses by qualitative and quantitative methods.

**Societal Impact:** Several countries have enforced strict laws to keep indoor air quality (IAQ) under check, but India is yet to catch up to this. Poor IAQ in offices

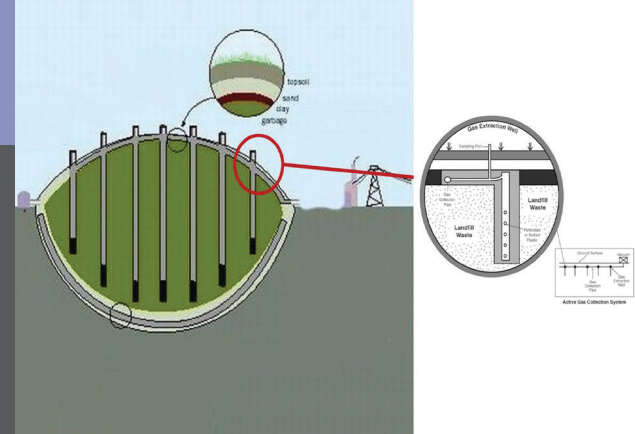
and residential societies with multi-level parking is alarming. The proposed product will improve overall air quality in offices and residential societies with multi-level parking. The product is best suited for urban localities and reduces the negative impact on human health and the environment.

**Patent(s):** Nil

**Relevant Industries:** Shopping Malls, Parking Lots.

**Faculty:** Prof. Anil Kumar Dikshit, Environmental Science & Engineering.

## Legacy / Old Dump Waste Management (LDWM)



**Problem Statement:** Disposable plastics, household and degradable waste, and discarded electronics are dumped in the large landfills and lie there in the open dumpsites for many years, creating what is called 'Legacy waste'. With the increasing population in cities, more waste is being produced, and more space is required for dumping these wastes. Scientific solutions to clearing Legacy waste is a problem that needs to be addressed and is the need-of-the-hour. A research team at IIT Bombay has developed a technology for provisions for dumpsite slope stabilisation, biogas and leachate capture, surface drainage and final cover.

**Uniqueness of the Solution:** The team introduced a novel method called the Dumpsite Rehabilitation system. The landfills are processed and utilised with the provisions for slope stabilisation, landfill biogas management and leachate capture, surface drainage and final cover. The garbage from the landfills is

processed by covering waste with layers of clay and sand and the topmost soil layer. The system is designed such that gas collection pipes are connected to garbage to collect biogas and peripheral pipelines for leachate collection. This LDWM system can be utilised by municipalities to deal with old dumpsites.

**Current Status of Technology:** The proposed technique is in the TRL 9 stage. The Legacy Waste Management System (LWMS) has been successfully implemented by Mira Bhayandar Municipal Corporation (MBMC) in 2016, Municipal Corporation of Greater Mumbai (MCGM) in 2018 and Lonavala Municipal Corporation (LMC) in 2018.

**Societal Impact:** These landfills or open dumpsites are a nuisance due to foul odour, stray animals and health hazards for the people residing nearby dumping sites. Implementation of the Legacy Waste Management System (LWMS) can help reduce the problems faced by the

people due to open dumpsites.

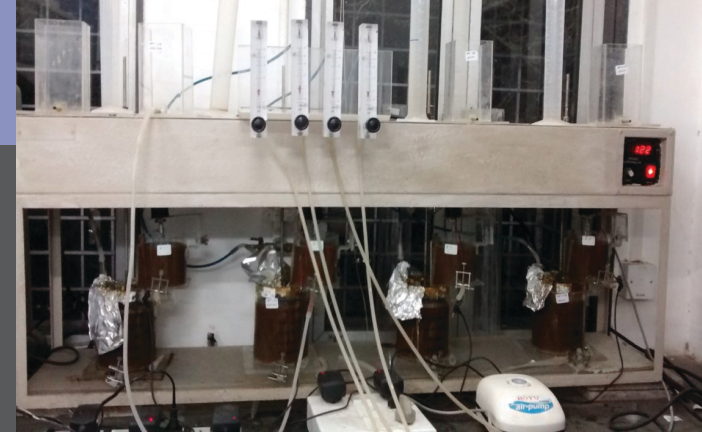
**Patent(s):** Nil

**Relevant Industries:** Cities, Towns, Urban Local Bodies, Municipalities.

**Faculty:** Prof. Anil Kumar Dikshit, Environmental Science & Engineering.



## Membrane Sequential Bio-Reactor for Decolorisation of Wastewater



**Problem Statement:** An eco-friendly and cost-effective biological treatment system is essential for sustainable wastewater solutions in today's world. However, the treatment process that decolourises the objectionable dark brown colour and reduces a large amount of organic matter present in raw wastewater to permissible limits is challenging. As a result, conventional wastewater treatment plants are incapable of producing high-quality effluent. Membrane Sequential Bioreactor (MSBR) is one of the promising technologies which not only has the intrinsic ability to provide high-quality effluent but, most importantly, meets stringent effluent standards.

**Uniqueness of the Solution:** The MSBR developed in Environmental Infrastructure and Clean Technologies (EICT) Laboratory after an extensive study on decolourisation of distillery wastewater has the ability to work in a non-sterile environment. The unique feature of MSBR is that the bio-reactor

does not require any dilution of the water prior to treatment. This saves the cost of procuring fresh water for the industries.

**Current Status of Technology:** The design and operation of MSBR for decolourisation of actual distillery wastewater is extensively tested in a lab-scale reactor with excellent results. However, a large prototype in an industrial setup is yet to be commissioned.

**Societal Impact:** Distilleries are one of the most water-intensive industries and generate about 8-15 L of wastewater per litre of alcohol produced. They produce ethanol and many ethanol derived products, which find applications in various industrial and pharmaceutical products. There are 300+ molasses-based distilleries in India, and this number is expected to grow further with the recent impetus given by the government to blend ethanol in petrol. A majority of these industries lack sustainable wastewater solutions which

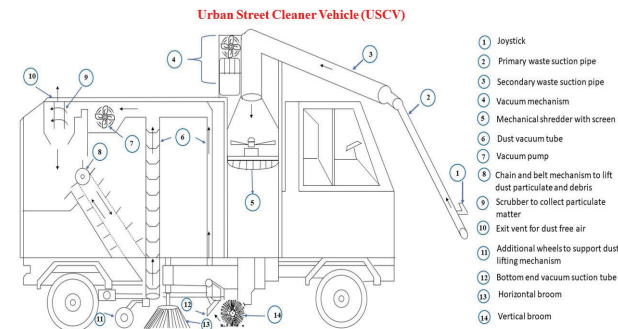
MSBR can provide. MSBR helps reuse treated wastewater, resulting in an overall reduction in freshwater requirements and safeguarding against surface and groundwater pollution.

**Patent(s):** Nil

**Relevant Industries:** Wastewater, Environment.

**Faculty:** Prof. Anil Kumar Dikshit, Environmental Science & Engineering.

## Mobile Urban Solid Waste Collector



**Problem Statement:** Population growth rate and infrastructure development have caused failure in collection methods and vehicle technology in urban cities, leading to uneven dumping and littering of solid waste across the city. Handling and managing huge amounts of solid waste generated daily is a daunting and challenging task. Over time, if these wastes are not collected properly, it leads to choking of drains, floating materials over the water bodies, making the urban landscape unclean and unattractive. The main aim of the present project is to provide solutions for handling waste littered in frequent dumping places which are neglected and not considered for collection.

**Uniqueness of the Solution:** The team has studied the requirements for developing different types of mobile units and tools for solid waste collection along the streets, railway tracks, coastlines etc. Since each type of media (waste) is different, the solution

is different. Therefore, there is a need to design, implement and test several mobile tools to be employed over large geographical areas. For example, mobile cleaning equipment will be developed for sweeping street surfaces. The tools consist of another set of equipment for cleaning unpaved/grassy/other surfaces. Whereas another mobile unit will be required for skimming muck floating over water surfaces. These units may also comprise built-in processing facilities such as segregation, shredding, baling, dewatering etc., depending upon waste characteristics.

### **Current Status of Technology:**

A preliminary study on existing collection and processing technology is completed and in the stage of TRL 1. The proposed technology will help improve the overall collection efficiency, followed by cost-effectiveness in SWM.

**Societal Impact:** There are insufficient vehicles that are not reaching every

corner of the cities for complete cleanup of the waste in public places. The waste collecting machine which is developed to target solid waste handling problems will be novel and innovative. Every tool/equipment / implemented and designed shall be of immense commercial value in the market.

**Patent(s):** Nil

**Relevant Industries:** Cities, Towns, Urban Local Bodies, Municipalities, Industries.

**Faculty:** Prof. Anil Kumar Dikshit, Environmental Science & Engineering.



## Multi-Utility Vapour Compression System



**Problem Statement:** Conventional VCS provides only air conditioning and cannot provide hot and/or cold utility with air conditioning. Thus, it is not capable of operating as a multi-utility system. It is required to add heat and mass transfer surfaces in VCS to get a multi-utility effect resulting in heating and cooling of the fluid streams and air conditioning. Addressing this need, researchers at IIT Bombay have invented an energy Multi Utility Vapor Compression System (MUVCS) wherein the judicious combination of Heat and Mass Transfer Devices (HMTD) facilitates hot and/or cold utility while conditioning air. This system is capable of conditioning different spaces and conditioning air with high relative humidity. The system is also capable of thermal storage when catering to part air conditioning loads. Multiple hot and cold utilities are co-generated to enable energy conservation, reduce emissions, reduce the use of refrigerants, low economic and environmental life cycle costs.

**Uniqueness of the Solution:** Novel patented Tube-Tube Heat Exchangers are used, which enable multi-stream heat exchange while offering high reliability and flexibility in terms of quantity and time of harnessing the utilities. The versatile design enables co-generation of air conditioning, water heating and water chilling utilities using a single system while integrating with process fluids while ensuring safety against the mixing of different streams. Once through the exchanger, heating and cooling of fluids through large temperature changes without the use of pumps. Initial and operating costs can be lower than the conventional air conditioner + electric water heater + water cooler while needing less space. The design also builds on an earlier invention that simplified integration using reliable Tube-Tube Heat Exchangers.

**Current Status of Technology:** Several exchangers have been demonstrated in the field, licensed and commercialised.

**Societal Impact:** The module significantly reduces carbon footprint, as energy-saving is 66 to 75% for heating while simultaneously catering to multiple cooling applications flexibly.

**Patent(s):** Filed and Granted

**Relevant Industries:** Automotive Industries, Food Processing Industry, Hospitality Industry, Residential Sector.

**Faculty:** Prof. M V Rane, Mechanical Engineering.

## Non-Invasive Point-of-Care Sensors for Monitoring Physiological Parameters from Bio-Analytes in Perspiration and Soil Nutrition

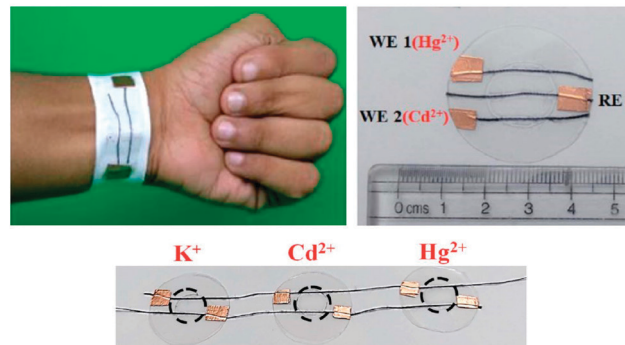
**Problem Statement:** Affordable and high-performing sensing platforms have become increasingly critical for sustainable environmental monitoring and medical diagnostics. Designing scalable and robust sensors poses an escalating demand in a rapidly automated society. A major challenge in realising such sensors is their operational reliability and reproducibility under widely varying conditions. Thus, developing an affordable and scalable sensing platform to detect important analytes in harsh environments reliably has been an enduring unmet challenge.

**Uniqueness of the Solution:** The current technology presents a scalable approach to achieve reliable, ultrasensitive detection of cations in harsh environments relating to physiological, water-quality monitoring and soil-nutrient assessment. The sensor exhibits identical performance under standardised laboratory conditions and real-time samples such as body fluids (sweat) and turbid water (lake). Both

these applications involve very specific detection of  $K^+$ ,  $Cd^{2+}$ ,  $Zn^{2+}$  and  $Hg^{2+}$  in ppb levels in the presence of a large excess (1000 times) of potential interferences (Na, K, Cu, N, Cl) and particulate matter that blocks and deactivates the sensing surface.

**Current Status of Technology:** The technology testing in both lab-scale and field-testing has been carried out. Similarly, a wide variety of soils from various parts of Maharashtra have been evaluated to assess micro-and macro-nutrients. Water samples from Powai lake are tested with the sensors, consisting of a reusable or use-and-throw patch (cost of < INR 5/patch). The technology for industrial adoption and validation is solicited.

**Societal Impact:** Point-of-care diagnostics is a rapidly emerging market in India with specific societal importance in the medical and agricultural sectors. This technology stands out in the

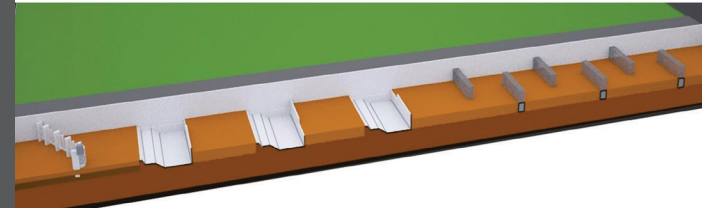


market because of its superior reliability, particularly under harsh field conditions, greater sensitivity without affecting the quantifiable outputs, low-cost making, and being suitable for scalable production.

**Patent(s):** Nil

**Relevant Industries:** Sensors, Agriculture, Healthcare, Environment.

**Faculty:** Prof. Chandramouli Subramaniam, Chemistry.



## NTreat: In-situ Nallah Treatment

**Problem Statement:** Nallahs or open drains are a common sight in our cities and villages. Floating Materials, silting, unpleasant odour, encroachment, disposal of debris and garbage are some of the problems associated with Nallahs. A solution is required to reduce these problems. The team has developed NTreat for the treatment of Nallahs, which can be used by municipalities and commercial establishments to treat the wastewater flowing in the Nallahs, thereby reducing adverse impacts of wastewater discharged to rivers and other water bodies.

**Uniqueness of the Solution:** The in-situ Nallah treatment NTreat is a simple process and uses natural treatment methods. NTreat can be constructed in RCC and deployed in any nallah. The treatment process and prototype involve different water treatment steps, where the floating materials and sediments are removed in the Primary treatment step. The first step is followed by treating water

using a natural method in secondary treatment. Finally, the process is repeated as per the quality of the water required as treated water.

**Current Status of Technology:** The newly proposed in-situ Nallah treatment is in its preliminary stage with TRL 9. Presently, the NTreat system has been perfricated in FRP and has been located next to a polluted drain in the lakeside on the IIT Bombay campus. It is being tested as a demo unit for a possible solution to treat drains in the Mahul Creek Area (a project sponsored by MMRDA). The cost of the product depends on the capacity, that is, the rate of flow needed in the nallah.

**Societal Impact:** This method can be used by municipalities and commercial establishments to treat the wastewater flowing in the Nallahs. The NTreat system can help to get rid of unpleasant odours and dirty nallahs. Thus, it will help improve the aesthetic environment for the

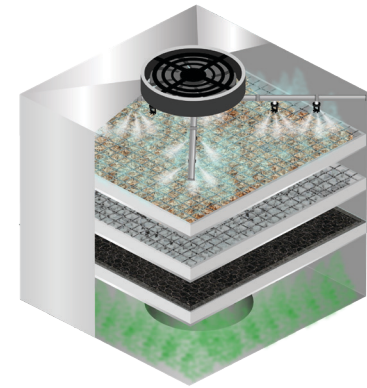
people living nearby Nallahs.

**Patent(s):** Nil

**Relevant Industries:** Cities, Towns, Urban Local Bodies, Municipalities.

**Faculty:** Prof. Anil Kumar Dikshit, Environmental Science & Engineering.

## Odour Control Equipment



**Problem Statement:** Odours are related to one of the most common air quality complaints, and constant exposure can, directly and indirectly, affect health and quality of life. Odour issues may arise due to the anaerobic decomposition of organic matter resulting in the release of odorous gases into the environment or by the direct release of odorous inorganic compounds from industrial sites. Thus, whether it is an industrial site, research lab or public place, the foul odour becomes a significant problem in terms of a nuisance and public health issue. Due to the increase in general public awareness regarding their quality of life and environment, odorous compounds emitting from any activity need to be curtailed. Therefore, recognising the urgent need to abate odour, the SINE IIT Bombay Company (EEPL) has developed a commercial Odour Control Equipment based on bio-oxidation property.

**Uniqueness of the Solution:** The Odour Control Equipment's unique feature is that

it uses a bio-filtration method to remove odorous compounds from the air stream. The system works on the basic principle of bio-oxidation, where microorganisms present in the biofilm filter digests the gases, particulate matter and volatile organic compounds in the presence of oxygen. The equipment consists of a moist, porous filter medium through which airstream is passed prior to emission into the atmosphere. The moist film, known as biofilm, works on the absorption-diffusion mechanism. Odorous compounds either accumulate in the biofilm or are digested by the resident microorganisms. Currently, available products in the market are mainly mechanical products, which use thermal energy to remove odorous compounds that require high operation and maintenance costs. In contrast, the bio-filtration methods for abating odour incur minimal operation and maintenance costs.

**Current Status of Technology:** The Odour Control Equipment is at the

prototype stage.

**Societal Impact:** Odour nuisance shrinks the social life of the human population in a civil society. Odour Control Equipment will help reduce odour nuisance, negative impact on public health, environment, economy and aesthetic of surrounding while improving air quality in and ultimately improving the social life of people.

**Patent(s):** Nil

**Relevant Industries:** Environment, Pollution.

**Faculty:** Prof. Anil Kumar Dikshit, Environmental Science & Engineering.

## Photocatalytic Membrane Reactor for Water Treatment

**Problem Statement:** According to an estimate, 700,000 tonnes of more than 100,000 different dyes are produced, of which 15% of dyes are directly released into the effluents. Like dyes, pharmaceutical compounds are also a major problem, and these compounds are present in ng/L; therefore, it is difficult to remove them from water. There are no cost-effective technologies to remove these contaminants. Hence, most dye and pharmaceutical industries do not treat their effluent, which leads to water pollution. These dyes, their byproducts, and pharmaceutical compounds are recalcitrant, carcinogenic, and very tough to degrade under natural conditions. In addition to their unacceptable appearance and toxic effect after their breakdown, they may contaminate the nearby soil, and surface water, becoming a major global environmental pollution challenge. Currently, technologies available to remove the dye and pharmaceutical compounds from water are adsorption, simple membrane

separation, ozonation, electro dialysis etc. However, these technologies are inefficient in removing dyes and most of the pharmaceutical compounds from water.

**Uniqueness of the Solution:** Photocatalysts have the ability to degrade organic compounds in the presence of UV or Sunlight. The IIT Bombay team is leveraging this advantage and developing the coupling system with a cost-effective hollow fibre membrane. This membrane will remove the dye and pharmaceutical compounds from contaminated water. In addition, the technology is used to make a low-cost photocatalytic membrane reactor and provide it to Indian industries.

**Current Status of Technology:** The Photocatalytic Membrane Reactor for Water Treatment is in the preliminary stages. Laboratory trials are being performed.

**Societal Impact:** The use of membrane

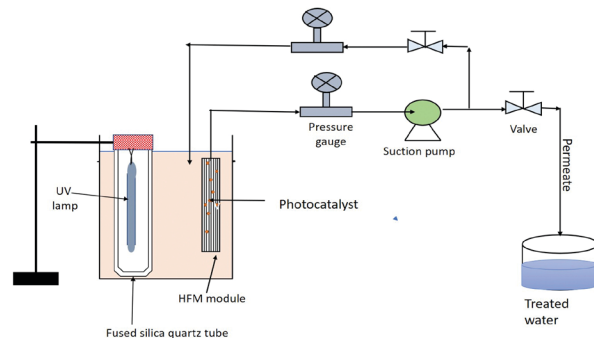


Fig: Photocatalytic membrane reactor for industrial dye and pharmaceuticals waste water treatment

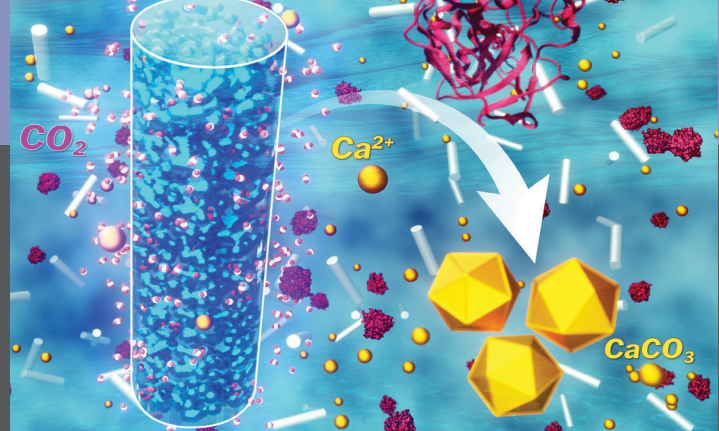
reactors helps to clean the effluent water to make clean water more accessible.

**Patent(s):** Nil

**Relevant Industries:** Water, Materials, Clean Energy.

**Faculty:** Prof. Jayesh Bellare, Chemical Engineering.

## Removing CO<sub>2</sub> from Atmosphere



**Problem Statement:** The greenhouse gases and their excessive emission from anthropogenic activities (fossil fuel combustion, deforestation, fertilisers) escalate environmental degradation. Carbon dioxide (CO<sub>2</sub>) emissions are 37 G tonnes per year worldwide, leading to disastrous environmental change. By 2018, only ~ 4-5 M tonnes of CO<sub>2</sub> per year had been captured and stored, which is much lower than the given guidelines by IEA. Thus, scientists' efforts are underway to overcome this; however, the ultimate solution to this problem will be to sequester, store, and convert the trapped CO<sub>2</sub> to industrially relevant materials. A type of porous liquids (that combines permanent and intrinsic porosity required for liquids to flow in pipes) has been developed and, available for sequestration and storage of CO<sub>2</sub>, has gained massive recognition. However, none of them converts CO<sub>2</sub> into industrially valuable products, which calls for developing catalytically active porous liquid. This team's work addresses this

issue.

**Uniqueness of the Solution:** The team has developed a composite porous liquid with a honey-like consistency at room temperature. The porous liquid comprises polymer surfactant (PS) grafted hollow silica nanorods and bioconjugated calcium carbonate (CaCO<sub>3</sub>). Silica nanorods enable the sequestration and storage of CO<sub>2</sub>. In contrast, bioconjugated carbonic anhydrase catalytically converts released CO<sub>2</sub> to carbonic acid (HCO<sub>3</sub><sup>-</sup>), which reacts with pre-added calcium chloride to form industrially relevant calcium carbonate. The synthetic process is facile and easily scalable.

**Current Status of Technology:** The recyclable sequestration, storage, and catalytic performance have been investigated at a laboratory scale and found to be an excellent method for sequestration.

**Societal Impact:** The technology is

beneficial for India and worldwide by helping sequestration/conversion of CO<sub>2</sub> into utility chemicals. It reduces CO<sub>2</sub> and converts it into industrially relevant and valuable products such as CaCO<sub>3</sub> polymorphs. It is applicable for healthcare, pharmaceuticals, agriculture, households, and many industries such as cement, glass, steel and paper.

**Patent(s):** Nil

**Relevant Industries:** Clean Energy, Materials, Environment.

**Faculty:** Prof. Kamendra P Sharma, Chemistry.



## Rotating Contacting Device



**Problem Statement:** Rotating Contacting Device, RCD, is a rotating device for the contact between gas and liquid flow in wastewater treatment. It enables efficient contact of liquid and gases to offer energy-efficient technologies for wastewater vapourisation using ambient air, cooling towers, humidifiers, evaporative condensers, biogas scrubbers, exhaust gas scrubbers, aerators, air cleaners, etc. An extra attachment or a device is of high priority to fast vaporisation by providing a large surface area for mass transfer between air, gas, or liquid types.

**Uniqueness of the Solution:** Modular Rotating Contacting Disk-based Mass and Heat Exchanger Technology is energy-efficient H&ME while offering high reliability and design flexibility in various applications. The device provides a greater surface area of contact between two fluids and maintains enabling rotation of disks with the help of liquid flow. It is operable over a wide range of liquid-gas

(L/G) ratios without flooding issues at very high L/G or effective wetting at low L/G. Modular design offers carryover free contacting with High Mass Transfer Coefficients using a textured rotating disk. Low air/gas side pressure drops, ~10 Pa, and a low pump head of ~3 m makes the unit energy efficient. The rotating disc is predominantly plastic, and composite disks of PP, PC, SS304, 316, 316L, Al, MS, etc., are possible according to fluid type. Issues like corrosion, erosion, fouling, catalytic activity, etc., can be resolved by online cleaning following clean-in-place using Jet Cleaning.

**Current Status of Technology:** Rotating contacting devices are demonstrated at the field, licensed and commercialised for wastewater vaporisation and indirect evaporative cooling.

**Societal Impact:** The device is energy-saving, environment-friendly, and reduces embodied energy.

**Patent(s):** Filed

**Relevant Industries:** Environment, Energy, Steel, Industrial Chillers.

**Faculty:** Prof. Milind V Rane, Mechanical Engineering.

## RoyAI: Pavement Subgrade from Industrial Byproducts



**Problem Statement:** Industries all over the world pose real-time challenges on disposal, handling and utilisation of byproducts. At present most of the industries dispose-off their byproduct material with no clues on bulk utilisation. The quantity and their hazardous characteristics pose a threat to the environment. One such byproduct is bauxite residues (BRs) generated from alumina. One ton of alumina generates approximately 0.8-1.5 tons of bauxite residues. Therefore, the primary objective of the present invention is to provide a bulk utilisation strategy by creating a composition for utilisation. We propose to prepare subgrades for constructing roads and pavements by using byproducts generated from alumina refinery and method thereof to cast in the field condition.

**Uniqueness of the Solution:** Unlike the conventional practice of making the subgrades of natural soils, this approach considers the use of industrial byproducts

with a small addition of a binder to stabilise it. The composite is poured in the semisolid state, which sets subsequently. This solution is relevant, especially when the pace of road network construction is high and with a scarcity of raw materials.

**Current Status of Technology:** The technology is tested on a pilot scale in the laboratory and proven to be feasible technically and environmentally in a real-life situation. It has been demonstrated at Utkal Alumina International Ltd., Odisha and Vedanta Alumina Refineries, Lanjigarh, Odisha, for a stretch of 50m. Further upscaling of the technology for rural road construction is under consideration.

**Societal Impact:** By creating policies and guidelines to include this byproduct as a resource for creating road networks, overall sustainable development of the society is expected with better connectivity between the places and reduced dependence on the natural

resources for road construction along with lower pollution load on the environment. With sustainability being the key to the growth and development of the nation, creating such facilities using sustainable materials is a boon to the industrial era.

**Patent(s):** Filed

**Relevant Industries:** Infrastructure Development, Sustainable Materials.

**Faculty:** Prof. D N Singh, Civil Engineering.



## StabMd: A Novel Technique to Stabilize Marine Deposits



**Problem Statement:** While it is already densely populated, India faces a scarcity of land and other natural resources for creating infrastructure facilities. We have acres of land used for dumping waste materials, whereas on the other end, large portions, particularly the coastal regions of India, have marine deposits. The marine components like clay and sediments are under-consolidated deposits; they exhibit lower shear strength and are prone to excess consolidation settlements under external loading. Planning any kind of infrastructure on these deposits is difficult unless stabilised. Hence, their stabilisation becomes of utmost importance.

**Uniqueness of the Solution:** Often, the marine sites with such deposits are inaccessible (due to the soft and sensitive nature of the clays and sediments). Hence none of the conventional stabilisation techniques can be attempted to achieve the desired objectives. Under these

circumstances, there is an alarming need to develop a methodology for stabilising marine deposits. The method should duly address the issues related to 'sustainable development' by employing the concept of industrial byproducts (IBPs) as a human-made resource. Keeping in view the issues mentioned above and stabilising marine deposits under in-situ conditions, the methodology StabMd was developed.

**Current Status of Technology:** The technology is ready with an optimum combination of industrial byproducts and execution methodology in the field. It is demonstrated in the in-situ condition to stabilise marine deposits at Navi Mumbai 4th container terminal.

**Societal Impact:** By stabilising marine deposits with industrial byproducts, overall sustainable development of the society is expected, with a vast area of land becoming suitable/ready for any type of development. It reduces dependence

on natural resources paving out a way to bulk utilisation of the industrial byproduct and lower pollution load in the environment.

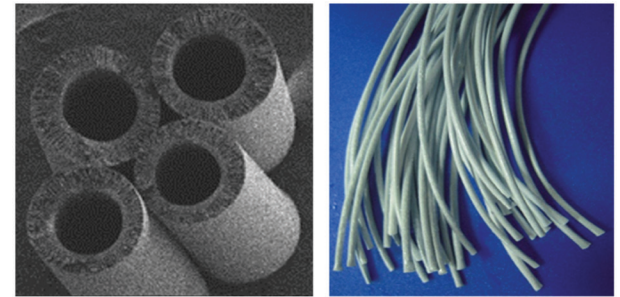
**Patent(s):** Filed

**Relevant Industries:** Alumina Refineries, Alcofine Manufacturers, Thermal Power Plants, Geotechnical Consultancy Groups.

**Faculty:** Prof. D N Singh, Civil Engineering.



## Tailored Hollow Fiber Nanocomposite Membranes for Wastewater Treatment



Nanocomposite Hollow fiber membranes

**Problem Statement:** The massive industrialisation has resulted in the discharge of toxic water contaminants, mainly oily water, heavy metals, and endocrine-disrupting chemicals, into the environment, causing several adverse health effects to living beings, even at low concentrations. Exposure to these toxic substances leads to organ damage, neurological development issues, and increased cancer risk. Therefore, there is an urgent need to separate contaminants from water bodies using advanced separation technologies, like membrane technology. The IIT Bombay team's invention has addressed the following two significant problems associated with membrane technology: Separation efficiency and Antifouling (flux recovery).

**Uniqueness of the Solution:** The tailored hollow fibre nanocomposite membranes for wastewater treatment are efficient, and membranes are low fouling. The hollow fibre membrane module is of  $0.004 \text{ m}^2$  active surface area, and the diameter of a

hollow fibre membrane is  $700\text{--}1000 \text{ }\mu\text{m}$ . The membranes products available in the market show a high separation efficiency, but they are prone to fouling, limiting their separation efficiency. The proposed membrane technology addresses the fouling concern without comprising separation efficiency using a close-to-real life system at the lab scale.

**Current Status of Technology:** The Proof-of-concept using this membrane is demonstrated at lab scale using close-to-real life systems (i.e. contaminant-spiked surface water as feed). The product holds significant potential in the national and international market and shows growth in wastewater technology products.

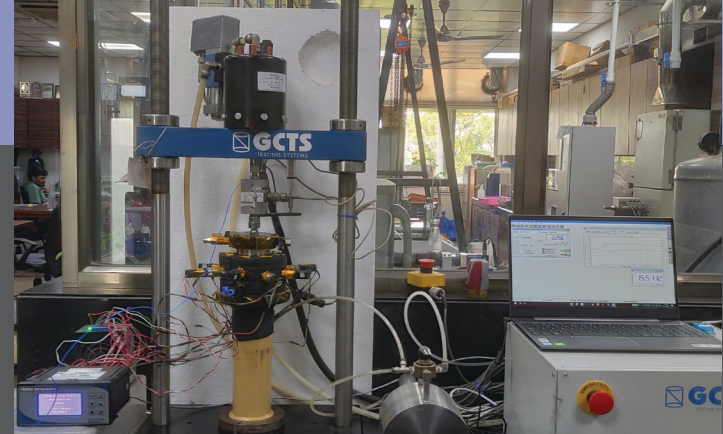
**Societal Impact:** The inventions offer a solution to remediate contaminants of emerging concerns from water, which directly affect the health of the society. Therefore this invention has a substantial societal impact.

**Patent(s):** Filed and Granted

**Relevant Industries:** Wastewater Treatment, Effluent treatment plants, Environment, Materials.

**Faculty:** Prof. Jayesh Bellare, Chemical Engineering.

## ThermCon-P: Thermal Consolidometer With Pore-Pressure Profiling



**Problem Statement:** Whether it is an underground utility such as cable wire or the design of a satellite launching pad, these activities generate heat near or surrounding the soil region. It will impact soil temperature and moisture, in turn impacting the soil ecosystem. The other contemporary activities of immense interest to researchers and professionals are the utilisation of geothermal energy, deep disposal of nuclear waste, pipelines and others. In any of these situations, soils get exposed to elevated temperatures resulting in the building up of pore-water pressure and suction in soil. Looking into the overall engineering properties of the soils change, it becomes essential to quantify them for the construction of these structures. The present study setup helps to determine these parameters and subsequently to design its foundation.

**Uniqueness of the Solution:** The invention of the thermal Consolidometer With Pore-Pressure Profiling facilitates

the estimation of thermo-mechanically induced consolidation of soils. The uniqueness of the setup is that the pore-water pressure and suction that builds up in the soil specimen are recorded appropriately. Data and analysis required to compute the consolidation of the soil under various thermo-mechanical testing conditions can be determined precisely. The setup is also capable of simulating various thermo-mechanical stress loadings on the soil specimen.

**Current Status of technology:** The setup is calibrated, and preliminary results obtained are promising.

**Societal Impact:** The overall engineering properties of the soils change, and it becomes essential to quantify them for the construction of these structures. The present setup helps to determine these parameters and subsequently to design its foundation.

**Patent(s):** Filed

**Relevant Industries:** Environment, Geology, Construction (Geotechnical).

**Faculty:** Prof. D. N. Singh, Civil Engineering.

## Zonal Storage Water Supply System with Hydraulic Isolation Structure (ZS-HIS)

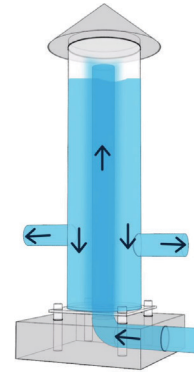
**Problem Statement:** In India, the Water Supply System (WSS) is stuck in a vicious cycle of failure. The drivers responsible for the situation are related to the design, analysis, operation, consumer satisfaction, and institutional capacity aspect of WSS. As a result, high non-revenue water (NRW), inequitable water supply, and deterioration of WSS are commonly found across India. The interventions applied to overcome the issues are generally proposed based on their performance in developed countries. However, such interventions fail to deliver in India. Moreover, the capital and operation and maintenance (O&M) costs of such interventions are higher, posing an additional challenge for improving the efficiency of WSS in India. The current research solution has addressed this issue.

**Uniqueness of the Solution:** The proposed methodology is based on rigorous surveys, field studies and using knowledge of field hydraulics. This

methodology is suitable to the Indian context and aims to provide low-cost and easy maintenance-oriented design and operation solutions to improve WSS in India.

**Current Status of Technology:** The system components have been tested in a real-life working environment. The performance of the shaft that acts as a hydraulic isolation structure was commissioned at the project site in Saphale, Palghar, Maharashtra, in December 2020. To date, the Shaft's performance is satisfactory, supplying water to consumers with adequate pressure.

**Societal Impact:** The technology has a huge societal impact as it provides low-cost and appropriate solutions for improving WSS in India. The technology helps deliver the objectives of the Jal Jeevan Mission of the Government of India, both in rural and urban areas. The Urban Local Bodies (ULBs), Public Health



Engineering Department (PHED), and other parastatal bodies responsible for planning, designing, and operating WSS in India will benefit from the proposed method.

**Patent(s):** Filed

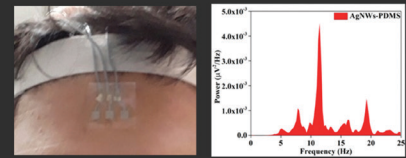
**Relevant Industries:** Urban Local Bodies (ULBs), Public Health Engineering Department (PHED), Municipal Corporations.

**Faculty:** Prof. Pradip Kalbar, Centre for Urban Science & Engineering.

# Flexible Electronics & Nanotechnology



# Implantable Electroencephalography (EEG) Probes for Neuro-Surgery and Neuro-Monitoring



**Problem Statement:** Neurological disorders are one of the important public health issues in India, with over 30 million people having common conditions such as epilepsy, stroke, tumours, Parkinson's disease and tremors. In many of these disorders, the first line of treatment is medication. However, surgical treatment is often necessary, for which diagnostics and monitoring by identifying the focal points are essential. One of the significant hurdles in neuro-surgical treatment is the prohibitive cost. Electrodes design can be drastically improved using the concepts of flexible and stretchable electronics such that a lesser area of the skull needs to be opened for surgery, provide better signals for localisation and significantly reduce the cost.

**Uniqueness of the Solution:** The team's indigenously designed electrodes are micro-scale electronic devices embedded in thin polymers, which can be rolled up and safely injected onto the brain surface without requiring larger

openings in craniotomy. The surface electrodes are very flexible, so they conform to the skull's contours, bringing all embedded electrodes in contact with the brain surface, providing better signal acquisition and hence better localisation of the problem zone.

**Current Status of Technology:** The team has developed a proof of concept of the technology of the flexible/stretchable electrodes embedded in polymers that can reliably pick up EEG signals from the forehead.

**Societal Impact:** Neuro-diseases are a major public health issue in India. The current finding can significantly reduce the cost associated with neuro-surgery.

**Patent(s):** Filed

**Relevant Industries:** Flexible Electronics, Nanotechnology, Healthcare.

**Faculty:** Prof. Dipti Gupta, Metallurgical Engineering and Materials Science.



**Healthcare (including devices and digital health)**

## 3-D Scaffold Matrix for Bone Reconstruction

**Problem Statement:** Surgeons often report several shortcomings in the currently available bone grafting products. The drawbacks prevent them from providing adequate care to treat bone damage. Most of the available bone grafts are in the form of powder, blocks or putty and lack membranes. They do not allow the surgeon to fill the defect wholly, leaving voids that prevent bone from growing. Several products are poorly handled, accounting for the loss of material, time and difficulty in insertion during the preparation on the surgery table. These materials on implantation and over time break free and move out from the defect site. Thereby bone formation is inadequate and of poor quality. IIT Bombay researchers developed a 3-D scaffold matrix for bone grafting and reconstruction, considering these drawbacks.

**Uniqueness of the Solution:** Membranes hold the materials stably and prevent infection post-surgery. The 3-D scaffold

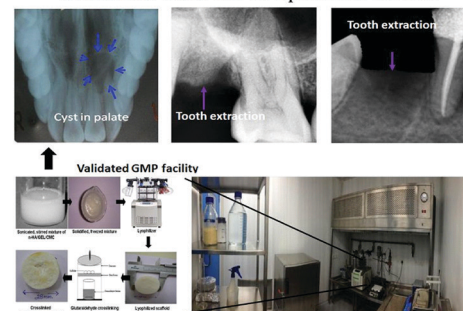
matrix (bone graft) helps surgeons grow bone faster in any type of irregular defect, with reduced surgery time and no membrane conditions, by completely filling the defect and increasing the stability at the graft site. The unique fabrication process offers a nano-surface on the walls of the micropores for higher cell attachment and migration.

**Current Status of Technology:** The researchers have completed a pilot clinical investigation using the 3-D scaffold matrix for treating alveolar ridge augmentation in 20 patients at AIIMS, New Delhi.

**Societal Impact:** Bone grafting is of great importance, and social relevance since most of the effective grafts are biologics and are imported, and the cheaper grafts are very inefficient. Imported grafts are inaccessible for Indian patients as biologics and incorporated grafts are costly. With the interest of equipping the doctors to deliver effective, competitive

### 3-D scaffold Matrix (Bone Graft)

Transition from lab to operation theatre



and affordable bone reconstruction treatment, the team envisages building competitive medical devices and products based on novel materials. It also revolutionises the healthcare system in India and other low-income countries and adds socio-economic values to society.

**Patent(s):** Under Progress

**Relevant Industries:** Healthcare, Manufacturing; Medical Devices

**Faculty:** Prof. Jayesh Bellare, Chemical Engineering.

## Aortic Valve Template

**Problem Statement:** More than 60,000 open-heart surgeries are performed annually in India, mainly for coronary and valvular heart disease. The current method to create an aortic valve from a patient's pericardium during surgery is inaccurate and not standardised. Measurements of the valve are taken manually, making it slow and cumbersome. The researchers have designed a solution specifically for the Indian population to overcome these challenges. This solution is a surgical tool to create an accurate profile of aortic valve leaflet from a patient's own pericardium tissue for valve replacement surgery.

**Uniqueness of the Solution:** As this research offers a solution to use the patient's pericardium to create the heart valve leaflets, it avoids the need for artificial valves. Based on the age of a patient, different sizes of the tools designed are selected to cut the parabolic shape of the aortic valve leaflet. The use

of this tool reduces the manual error, need for high skill and time required for such a surgery. In addition, post-surgery medications (that have side effects) can also be reduced.

**Current Status of Technology:** The researchers have manufactured the functional prototype of the device. The preclinical testing of the aortic valve template has been carried out. The researchers have ensured the biocompatibility of the material used for manufacturing the device. Cardiac surgeons from renowned hospitals in Mumbai are currently testing this solution.

**Societal Impact:** The product reduces the surgery time, the cost of the surgery and also the number of medications required post-surgery. Thus the surgery is made more affordable for everyone. It also reduces the chances of infections as compared to mechanical valves as the patient's own pericardium is used. Thus the solution improves the well-being of



patients undergoing valve replacement surgery.

**Patent(s):** Filed

**Relevant Industries:** Healthcare, Medical Devices, Biomedical Engineering.

**Faculty:** Prof. Bhallamudi Ravi, Mechanical Engineering.

## ATR-FTIR Spectroscopy for Detecting Severity of COVID-19

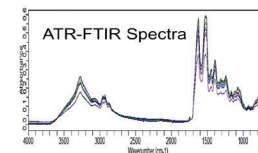
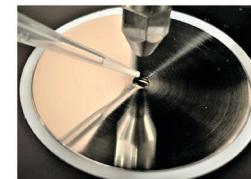
**Problem Statement:** India saw a huge number of cases during the second wave of the COVID-19 pandemic that put immense pressure on the medical infrastructure. Appropriate medical facilities were at times not available to those who had severe symptoms and needed them the most. The golden test to check for COVID-19, the RT-PCR test, can only tell whether a person is infected or not. Unfortunately, the test cannot determine the severity of the infection or predict how severe the symptoms of an infected person could become. The researchers have addressed the challenging problem of prognosis of the severity of COVID-19 disease by designing a simple, rapid test called ATR-FTIR (Attenuated total reflectance-Fourier transform infrared) Spectroscopy. It can be conducted at the point of patient admission and can help transform hospital management during crises.

**Uniqueness of the Solution:** The ATR-FTIR Spectroscopy test gives information

about the severity of one's COVID-19 infection, which other diagnostic tests do not provide. The simplicity of the sample preparation and spectral acquisition methods are the unique features of this test. Therefore, it can be quickly undertaken by clinical laboratory personnel.

**Current Status of Technology:** The researchers have demonstrated experimental proof of concept for this work and performed a blinded test (where the test is masked from the participant's knowledge to eliminate bias until after the trial outcome is known).

**Societal Impact:** ATR-FTIR is a promising technology for rapid, real-time COVID-19 triaging. It is an ultra-compact and flexible benchtop instrument that can easily be employed in the hospital setting. It can help hospital management take timely action by identifying the severity and risks faced by patients who have tested positive for COVID-19. The researchers



envisage that the product will be in high demand in global markets for COVID-19 prognosis.

**Patent(s):** Filed

**Relevant Industries:** Healthcare, Medical Devices.

**Faculty:** Prof. Sanjeeva Srivastava, Biosciences & Bioengineering.

## Bicondylar Compression Screw



**Problem Statement:** Bicondylar fractures are commonly treated using non-operative methods like plaster cast immobilisation, skeletal traction and functional cast bracing. Operative procedures of treatment include internal stabilisation of the fracture with screws alone or with a combination of plate and screws or external stabilisation with a fixator frame applied around the limb. Tibial (shin bone) fractures are one of such fractures. The researchers have addressed the need to make the operative treatment quicker and easier by developing a novel bicompression screw to be used by orthopaedic surgeons for fixing bicondylar fractures.

**Uniqueness of the Solution:** The proposed bicondylar compression screw, made of a biocompatible material, offers a rigid compression to the bicondylar fracture. It provides the early weight-bearing capability to the bone and early union of fractures. The novel technology provides a stable, congruent and smooth

joint surface of the upper end of the tibia (shin bone) so that there is complete recovery of the knee joint function. This product can be used in all types of condylar fractures with a reduced cost compared to existing implants and screws commonly used.

**Current Status of Technology:** The researchers have established the proof of concept. Metal prototypes in biocompatible stainless steel material have been manufactured and tested in preclinical settings. The approximate cost of the product material and manufacturing is INR 5000.

**Societal Impact:** This novel bicondylar compression screw technology helps avoid the need to use multiple screws and plates to fix the fractures using operative treatment. It is beneficial and less stressful for the surgeons and patients by resulting in a reduction in the duration of surgery. The features of this technology aim at complete recovery of the knee joint

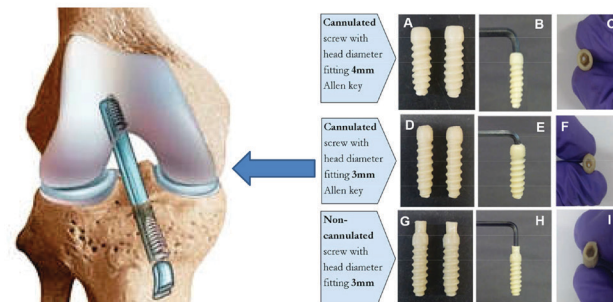
function.

**Patent(s):** Filed

**Relevant Industries:** Healthcare, Medical Devices.

**Faculty:** Prof. Bhallamudi Ravi, Mechanical Engineering.

## Bioresorbable Screw for ACL Repair



**Problem Statement:** Bioabsorbable or metal screws are used for bone grafting. Although both have similar fixation strengths, bioabsorbable screws eliminate the need for removal and easier postoperative imaging. But bioabsorbables increase inflammatory response, risk of screw breakage, incomplete screw absorption or tunnel widening. In addition, inappropriate grafting technology might lead to bone loss; thus, choosing an appropriate product is crucial. However, currently, the available products have many shortcomings. For example, although several non-absorbable and resorbable polymeric devices are available in the market, they are not radiolucent, which hinders the post-surgical follow-up of the repaired part, and many don't promote bone regeneration. This research team's innovative design overcomes these drawbacks.

**Uniqueness of the Solution:**  
Bioresorbable screws with an advanced

biomaterial technology platform is a one-stop solution for developing a wide variety of resorbable bone-soft tissue fixation devices like bone screws, plates, suture anchors, etc. The product is cost-effective and matches the required stress and mechanical demands of specific target human tissue. These screws comprise bioactivity and tool kit compatible parameters, are entirely resorbable, have far superior imaging compatibility, and have tunable mechanical strength and prevent infection.

**Current Status of Technology:** The technology is evaluated preclinically and found to be safe. It is currently at TRL-5 as per BIRAC medical device guidelines.

**Societal Impact:** These bioresorbable screws significantly reduce the cost per screw as they use cheaper and readily available raw materials and in-house development and manufacturing of bioresorbable bone-soft tissue fixation devices. The novel screws will fulfil the

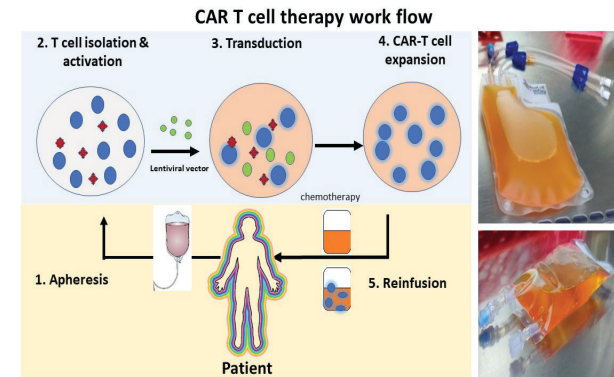
unmet socio-economical medical need of economically weak end-users. These resorbable screws help surgeons who want to fuse bone faster and provide better post-surgical care by growing the bone and minimising the risk of infection.

**Patent(s):** Filed

**Relevant Industries:** Healthcare, Manufacturing, Medical Devices.

**Faculty:** Prof. Jayesh Bellare, Chemical Engineering and Prof. Rohit Srivastava, Biosciences & Bioengineering.

# CAR-T Cell Therapy (Gene Therapy) to Cure Cancer



**Problem Statement:** Cancer is deadly and is growing increasingly aggressive over the decades, claiming the lives of adults and children globally. Today, 2.25 million people per year are affected by different cancers. The majority of available cancer therapies prolong life by a few months only. A new technology, called CAR-T cell therapy (a type of gene therapy), was developed to cure cancer. This technology platform showed remarkable success in curing relapsed or refractory r/r B cell malignancies, including B-ALL, DLBCL, FL. However, the treatment is exorbitantly costly, approximately USD 400,000-500,000 (INR 3-3.5 crores) for each patient. In India, this technology is not yet available at any price. As a result, the majority of the patients resort to palliation and inevitably die.

**Uniqueness of the Solution:** The team has developed an in-house, robust and affordable CAR-T platform to treat blood cancers. This project is a first in India and

provides end-to-end indigenous solutions for gene therapy in a GMP compliant process and infrastructure. IIT Bombay's novel CAR-T cell product is patented and has undergone extensive pre-clinical characterisation and scale-up. Since the entire process flow, from R&D to first-in-human clinical trials, is wholly indigenous, successful translation at a fraction of the cost ( $1/_{10}$ th of the cost of therapy available outside the country) is possible.

**Current Status of Technology:** The team's first CAR-T cell product for certain types of leukaemia and lymphoma is currently under the first-in-human clinical trials in India. After pre-clinical characterisation, the team has developed scalable processes as per the industry and cGMP standards for manufacturing CAR-T cells for use in patients.

**Societal Impact:** CAR-T cell therapy is unavailable in India and is exorbitantly costly outside. This CAR-T cell therapy, being indigenous, would be available

for most patients in India. The expected price would be in the range of stem cell transplant costs in the country, approximately INR 30 lakhs per patient.

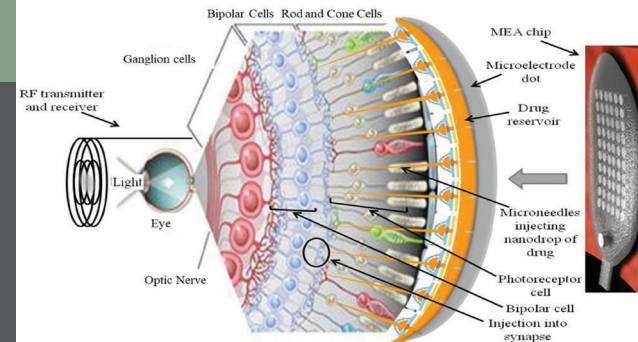
**Patent(s):** Filed

**Relevant Industries:** Biomedical Technology, Cell Transfer Therapy.

**Faculty:** Prof. Rahul Purwar, Biosciences & Bioengineering.



## Chemoretina: Vision Restoration Using Voltage-Gated Sodium Channel Modulators



**Problem Statement:** Several hereditary degenerative diseases such as retinitis pigmentosa (RP), age-related macular degeneration (AMD) etc., cause structural and functional damage to neurons in the retina. Patients afflicted with these diseases gradually lose their vision and become legally blind within a short period. Of these diseases, RP is primarily characterised by progressive degeneration of photoreceptor cells leading to loss of phototransduction apparatus. Researchers from IIT Bombay have explored the possibility of stimulating retinal bipolar cells in an attempt to restore vision.

**Uniqueness of the Solution:** Studies on the intra-vitreous injection of a voltage-gated sodium channel blocker Lamotrigine show an electronegative electroretinogram (ERG) response in rats and goldfish, suggesting a signal disruption between photoreceptor and bipolar cells of the retina. Since functional vision loss is primarily due

to loss of signal transmission at the photoreceptor-bipolar cell level, the team explored the possibility of stimulating retinal bipolar cells (RBCs) in an attempt to restore vision. The researchers are presently determining RBC response to different types and patterns of light in a healthy retina and comparing them to their response in a degenerating retina. Since sodium currents form a significant component of visual signal transmission along the photoreceptor-bipolar-ganglion cell pathway, the researchers attempt to understand the effects of voltage-gated sodium channel modulators on RBC signalling. The study will help identify a suitable method to exploit sodium channels to re-induce signal transmission in cases of degeneration.

**Current Status of Technology:** Primary research is done. The researchers welcome partners to drive the feasibility tests towards human and animal trials.

**Societal Impact:** One in 750 adults and

13 in every 740 adults in rural central and south India, respectively, are affected by RP. The research team envisages a tremendous societal impact if their idea can be taken to the market level.

**Patent(s):** Filed

**Relevant Industries:** Healthcare, Medical Devices.

**Faculty:** Prof. Jayesh Bellare, Chemical Engineering.

## Clubfoot Module



**Problem Statement:** Every year in India, more than 50,000 children are born with clubfoot, a congenital deformity in which the child's foot appears rotated inwards at the ankle. The condition is usually treated by a non-invasive correction procedure by fitting a foot abduction brace (FAB). The FAB is a fixed metal bar attached to two shoes with laces and a strap to hold the foot firmly in position. Recurrences following clubfoot correction can be prevented by regular use of the brace until the child is four to five years old. However, there is a lack of an objective method to measure actual hours of brace usage. The researchers present a clubfoot brace module for monitoring the FAB to address the need to capture brace usage data and monitor brace adherence to reduce recurrence rates.

**Uniqueness of the Solution:** The researchers have developed a module that can be placed inside the brace. Sensors in the module capture the brace usage data every 15 minutes and store

it locally on a data card. BLE-based (Bluetooth Low Energy-based) wireless transmission system sends the data from the brace daily to a remote cloud server via a smartphone application. The sensors record this data, and a web-based application helps to visualise it in real-time. The system has already been tested in a pre-clinical setting, demonstrating its feasibility in clinical practice. Prototype devices with similar features have been reported by a few research labs, but none of them are available in the market yet.

**Current Status of Technology:** The functional prototype of the clubfoot module has been developed, and bench testing of the device is completed.

**Societal Impact:** The Clubfoot module can accurately measure and remotely transmit brace usage data. It has the potential to transform caregivers' behaviour towards brace adherence, which could result in a tangible reduction in recurrence rates. Reduction in

recurrence rates helps prevent future disabilities and improve the quality of life in the affected children.

**Patent(s):** Filed

**Relevant Industries:** Healthcare, Biomedical Engineering.

**Faculty:** Prof. Bhallamudi Ravi, Mechanical Engineering.

## Controlling Fat Secretion from the Liver

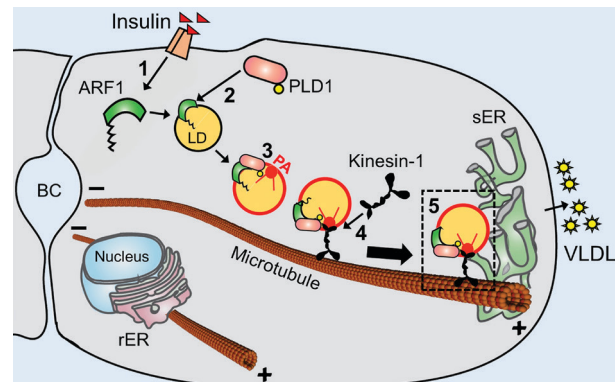
**Problem Statement:** The Liver packages fat and cholesterol into Very Low-Density Lipoprotein (VLDL) particles and then releases VLDL into the blood for delivery to different organs where fat and cholesterol is utilised. When this equilibrium is disturbed, it manifests into diseases such as obesity, diabetes, dyslipidemia, cardiac problems, or fatty liver. This team discovered a mechanism that controls how much fat is secreted from the liver into the blood. They show that the nanoscale motor protein Kinesin-1 delivers fat molecules to a specific location in the liver from where it is repackaged into VLDL particles and circulated in the blood. With an understanding of this fundamental mechanism now available, they propose to intervene in a targeted manner that may benefit patients with chronic dyslipidemia and/or fatty liver.

**Uniqueness of the Solution:** This discovery is a first-of-its-kind intervention via this pathway as the mechanism that

controls VLDL secretion through Kinesin motors. Furthermore, it has been proven to work in a cell culture model and in rats; it also provides very selective and targeted intervention. As their next steps, the team envisages finding better and more specific inhibitors of Kinesin on fatty particles and collaborating with industry experts in drug formulation and delivery.

**Current Status of Technology:** A peptide that specifically blocks fat secretion from the liver by preventing the Kinesin motor from docking on fat bodies has been identified. The team has also shown that it is possible to control this mechanism through external intervention in cultured cells and rats. They now look for higher affinity peptides and peptidomimetic drugs that can be delivered to the liver for further progress. Another possible direction is targeted gene delivery that could be attempted using an adeno-associated virus.

**Societal Impact:** Targeting a novel



pathway that controls fat circulation in blood could help control the epidemic of obesity, diabetes and accompanying maladies.

**Patent(s):** Nil

**Relevant Industries:** Pharmaceutical with experience in drug formulation or delivery.

**Faculty:** Prof. Roop Mallik, Biosciences and Bioengineering.

## Corona Surrogate Virus Trapping Device

**Problem Statement:** Doctors and healthcare workers are the most vulnerable to coronavirus infection, specifically while performing a surgery. COVID-19 infected individuals who need surgery by Laparoscopy should be operated on with the utmost care due to the chances of virus carryover through the pneumoperitoneum gas. The aim of this study was to completely remove the virus entrapped in the aerosols of pneumoperitoneum gas stream by passing it through the modified polysulfone/polyvinyl pyrrolidone (P) hollow fibre membranes (HFMs). The developed device provides a low-cost solution to protect healthcare workers from the virus; if not, at least decrease the viral load.

**Uniqueness of the Solution:** The Corona Surrogate Virus Trapping Device could be the only HFM based device in the market for its application in operation theatres. This device efficiently removes the virus without affecting the pressure drop in the

laparoscopic exhaust line. These HFMs-based products have ~98.99% removal efficiency toward bacteria when tested on agar plates using samples from the gas streams. In addition, the preliminary virus studies showed 10<sup>5</sup> orders of magnitude reduction in virus (surrogate coronavirus).

### Current Status of Technology:

The virus trapping device is ready for demonstration in an operational environment. The device consists of a bunch of porous HFM, which can trap coronavirus in its pore. In addition, a UV lamp is attached in series to the HFM module for higher safety. The device is ready for transfer to the industry.

**Societal Impact:** The healthcare system is at the epicentre of this unprecedented global pandemic challenge. Healthcare workers on the front line are most susceptible to catching the virus. The product could be useful in every laparoscopic operation theatre. It will help protect healthcare workers or at least

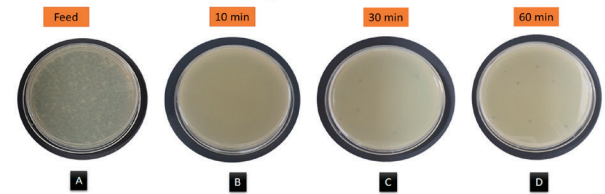
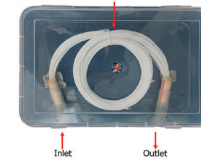


Figure 2: Agar plates showing plaques formed by the virus A) inlet to the module (B) after 10 min, (C) after 30 min and (D) after 60 min of experiment at the exit of the module



Hollow fiber membrane module

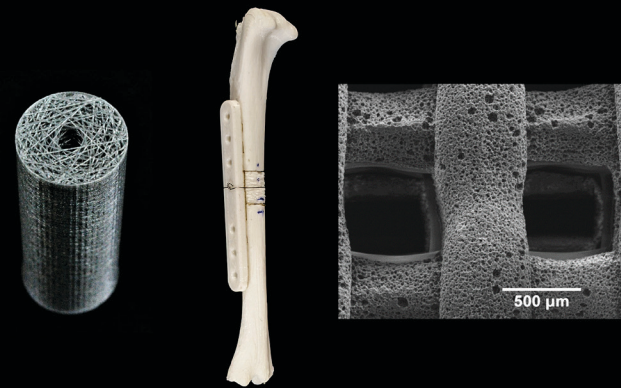
decrease the viral load, which can save their life.

**Patent(s):** In the process

**Relevant Industries:** Healthcare, Air Handling Units, Endoscope Manufacturers, Insufflators, Materials.

**Faculty:** Prof. Jayesh Bellare, Chemical Engineering.

## Customised 3D-Printed Bone Graft



**Problem Statement:** Currently, autograft is the gold standard for bone grafting, which is, however, most painful and costly and has a high morbidity period. Moreover, autograft deteriorates the patient's financial and social life. Also, there is no patient-specific, biodegradable, ready-to-use synthetic bone graft in the market. A biodegradable, faster bone generation and cost-effective bone graft method are needed. The customised 3D-printed bone graft developed by the IIT Bombay team addresses these shortcomings by providing an affordable, patient-specific, ready-to-use device, thus impacting a large section of the society, including the economically weaker sections.

**Uniqueness of the Solution:** The 3D printed bone graft has a novel gradient 3D mesh mimicking human bone. In addition, the graft is custom-made, biodegradable, and favours faster bone generation.

### **Current Status of Technology:**

The team has completed the market survey; they have identified the available technologies and their limitations prior to development. The implant design and scaffold fabrication procedure is ready and has been successfully executed with lab-grade materials. The materials and composition have been finalised based on competitor analysis and patent landscaping.

**Societal Impact:** In India, of the patients who suffer from bone loss or defects annually, approximately 15% of patients avail the bone graft services available in the market. These are the patients who need bone grafts for their treatment. Further, only 20% of these make it to treatment for bone grafts and substitutes. In addition to this, 5% of the total patients need bone grafts for cosmetic purposes. Thus, a total of nearly 6-7 lakh patients annually will be directly benefited from the proposed innovation. Furthermore, this product provides an affordable

patient-specific ready-to-use device, thus impacting a large section of the society, including the bottom of the pyramid is possible.

**Patent(s):** Filed

**Relevant Industries:** Bonegraft and Implant industries

**Faculty:** Prof. Jayesh Bellare, Chemical Engineering.

## Endo Retractor



**Problem Statement:** Laparoscopic cholecystectomy surgery is the commonly performed minimally invasive laparoscopic surgical procedure for removal of the gall bladder from the patient's body. Around ten million laparoscopic cholecystectomy surgeries are performed annually worldwide. In the cholecystectomy procedure, laparoscopic devices or instruments are used to retract and anchor the gall bladder (inside the body cavity). Currently, the existing surgical devices used in laparoscopic cholecystectomy surgeries for retracting the gall bladder are expensive and not reusable. The research team has addressed this drawback and designed an innovative laparoscopic surgical device/instrument called Endo-retractor. The novel instrument design will help surgeons perform surgeries in less time and facilitate less stressful surgeries, thereby aiding the effortless and efficient gall bladder removal during these surgeries.

**Uniqueness of the Solution:** The Endo-retractor is a small device with a simple design. The retractor offers an affordable solution. The instrument is expected to benefit laparoscopic surgeons by making it easier for them to anchor and lift organs, thus reducing surgical complications and internal tissue damage for the patient. The novel design of this Endo-retractor makes laparoscopic cholecystectomy surgeries simpler, less stressful, less time consuming for the surgeons, and in turn cost-effective for the patients.

**Current Status of Technology:** The proposed concept is at TRL 3. The researchers have demonstrated the initial proof-of-concept for device candidates in a limited number of laboratory models. The estimated cost of the device is INR 1,000 per piece.

**Societal Impact:** Endo-retractor based surgeries will be affordable with less internal tissue damage and beneficial

to the patients. The surgeons will also benefit as the instrument enables effortless and efficient surgeries.

**Patent(s):** Filed

**Relevant Industries:** Healthcare, Medical Devices.

**Faculty:** Prof. Bhallamudi Ravi, Mechanical Engineering.



## Frugal Microfluidic Device for Drug Screening and Testing

**Problem Statement:** Drug screening is performed to select the most effective molecule from the bucket of a few potential candidates. The effectiveness of a potential drug is estimated by treating target cells with various concentrations created manually in multi-well plates. This method is prone to human error and demands significant time and energy. Furthermore, the complexity increases enormously if combinations of drugs are to be tested. Although various flow-based microfluidic assays have been proposed to create concentration gradients, they are cumbersome and difficult to use. Hence, a simple, user-friendly yet inexpensive system is needed for easy in vitro testing of potential drug molecules.

**Uniqueness of the Solution:** The proposed device is a static (without flow) gradient generator that can be fitted in a single well of a six-well plate. Tens of combinations of multiple drugs can be tested in a single device, making the process fast, inexpensive and user-

friendly. The device does not need any external accessories such as pumps and tubing; it is portable and can be used “off the shelf”. Various post-treatment studies, such as immunofluorescence assays, are possible in this device. Also, as a continuous flow of media is not needed, it saves the cost of expensive reagents and precious patient samples.

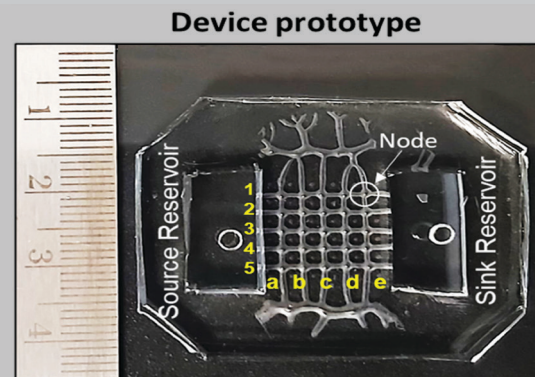
**Current Status of Technology:** The device is ready and tested for at least two different drugs on two different cell types.

**Societal Impact:** The proposed device will bring down the time and cost involved in drug testing. The device is inexpensive, ready-to-use and portable, thereby making it transport friendly to remote areas. As it does not involve any other accessories or expertise, it will help low-budget research labs and pathology-clinics to screen drugs faster and efficiently.

**Patent(s):** Filed

**Relevant Industries:** Pharma, Medical Devices.

**Faculty:** Prof. Abhijit Majumder, Chemical Engineering and Prof. Prasanna Gandhi, Mechanical Engineering.





## Indigenous Membrane Cartridges for Hemodialysis

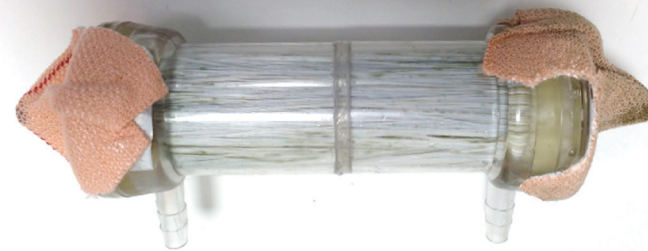
**Problem Statement:** Most hemodialysis instruments, accessories, and consumables are imported in India, including the Hemodialysis Fistula Maturation (HFM) dialyser. Indigenous dialysis cartridge development is the country's unmet demand and needs for quality and affordable healthcare requirements. There are lakhs of patients suffering from kidney failure and are heavily dependent on dialysis using imported cartridges. However, only one-third of the patients can afford this treatment. Even though the technology itself is well known and doable in India, it requires coordination among various domain expertise for improvisation in terms of cost-effectiveness and performance.

**Uniqueness of the Solution:** The researchers have developed a novel composition of dialysis-grade membranes at low-cost prices. These indigenous membrane cartridges exhibit excellent compatibility with human blood. In

addition, these have high uremic toxins removal efficiency and high permeation flux with minimal side reactions.

**Current Status of Technology:** While the animal trials are underway, the experiments in later stages will be on humans to reduce the risk of failure of the dialyser developed. The preliminary results suggest the performance of the developed membranes is far better than that of the commercial ones, and hopefully, these will be tested on the large animal models.

**Societal Impact:** India is prone to be a dialysis hub due to increasing diabetes and cardiovascular patients. From the Indian point of view, most dialyser instruments, accessories and consumables are imported – a reason why the foreign companies have a monopoly in the Indian market and generate massive revenue. However, the success of the proposed technology will lead to indigenous, low cost, high



performing hemodialysis membranes. Therefore, it has a high potential to fulfil the existing unmet demand of hemodialyser at an affordable price, thus impacting a large section of society.

**Patent(s):** Filed and Granted

**Relevant Industries:** Healthcare, Medical Devices, Materials.

**Faculty:** Prof. Jayesh Bellare, Chemical Engineering.

## i-WRIST: Electronically Lockable Health Monitoring and Tracking Device

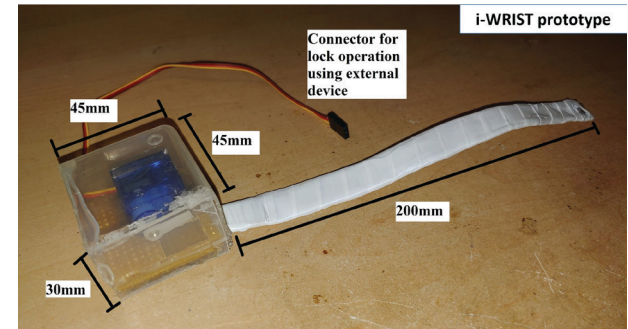
**Problem Statement:** The doctor-to-patient ratio is 1:1500 in India, and it overburdens the healthcare system posing several challenges to society, especially during a pandemic condition like COVID-19. Moreover, the unavailability of digital monitoring introduces risks for the patients and has impacted Indian patients. The IIT Bombay research team's proposed novel solution, called i-WRIST, not only helps in remote monitoring of health but can be extended to other therapeutic areas.

**Uniqueness of the Solution:** i-WRIST TechnoSol is an indigenous Wearable Reliable Intact Symptom Monitoring and Tracking wrist band and a Technology Solution. It is IoT based, lightweight, and waterproof wearable digital monitoring device to continuously 'track and trace' the patient's vital body parameters. Digital healthcare monitoring will help reduce the workload from healthcare professionals like doctors and paramedic staff. As of now, there is no direct competitor for

i-WRIST TechnoSol except commercially available wristbands, and digital watches are the indirect competitors. The proposed i-WRIST device will comply with the medical device standards, while the commercially available monitoring devices do not.

**Current Status of Technology:** The laboratory testing of the integrated system is completed. The results obtained from the testing are satisfactory and match with the commercially available devices. The researchers are working on the integration of complete system and alpha testing. The approximate cost of i-WRIST TechnoSol is expected to be INR 6000-7000 per device.

**Societal Impact:** The proposed i-WRIST can help track the parameters of remotely located patients and facilitate faster treatment. It can reduce the work burden on healthcare professionals and can create an overall positive social impact on the healthcare system.



**Patent(s):** Filed

**Relevant Industries:** Medical Device Manufacturing, Biomedical Engineering.

**Faculty:** Prof. Maryam Shojaei Baghini, Electrical Engineering.

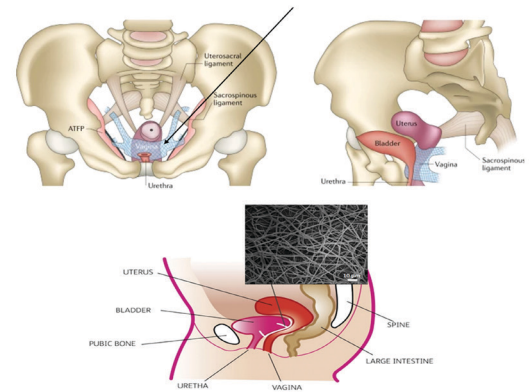
## Mesh for Pelvic Organ Prolapse

**Problem Statement:** Women above the age of 40 are prone to pelvic floor weakening because their bodies lose their ability to hold pelvic floor organs like the uterus, bladder, and rectum. Pregnancy, childbirth, chronic constipation, obesity and ageing are the usual causes for pelvic floor weakening. As a result, women experience pelvic prolapse and incontinence, leading to various degrees of prolapse. A lower degree prolapse can be reversed by lifestyle modification. But for higher degree conditions, a mesh has to be surgically inserted in the pelvic floor like a hammock to hold the organs. Initially, polypropylene-based non-degradable meshes were used, but USFDA banned them in April 2019 as they caused dyspareunia and organ perforation, compromising the quality of life for the women. This team has addressed the issue by proposing a design that overcomes the drawbacks, making a safer and biocompatible pelvic floor mesh.

**Uniqueness of the Solution:** The team aims to create a soft, lightweight, bioresorbable, biocompatible electrospun mesh that matches the pelvic floor's biomechanical property and helps tissue regeneration as the mesh gradually degrades. In addition, unlike the earlier polypropylene-based meshes, which compromised women's quality of life, the proposed mesh is safer.

**Current Status of Technology:** The team has demonstrated the proof of concept. Basic implant design is ready, and suitable materials are shortlisted. They have also done the required market surveillance and competitor analysis. Product specifications are defined based on competitor analysis and patent landscaping, and the Freedom to Operate (FTO) is ensured.

**Societal Impact:** According to a 2020 estimate, about 65 lakh women in India require pelvic mesh. There is a sharp decline in India's female labour force



participation rate, especially in the age group 35-40. The issue of prolapse contributes to this decline indirectly. Due to the USFDA ban, currently, there is no product available in Indian and the world market to treat prolapse and incontinence. The proposed mesh-based treatment for pelvic organ prolapse will improve the female labour force participation rate.

**Patent(s):** Filed

**Relevant Industries:** Healthcare, Medical Technology, Medical Devices.

**Faculty:** Prof. Jayesh Bellare, Chemical Engineering.

## Nanomedicines: Scientific Way of Potentization of Homoeopathic Medicines

**Problem Statement:** Homoeopathy is a system of alternative medicine based on the belief that our human body has the capability to cure itself. Homoeopathic remedies are prepared to consist of ultra-high dilutions, leading modern scientists to believe that homoeopathy may be a placebo. Therefore, the researchers have made efforts to deliver a new scientific method of preparing homoeopathic medicines, which may convince the scientists of the presence of active ingredients in the medicines.

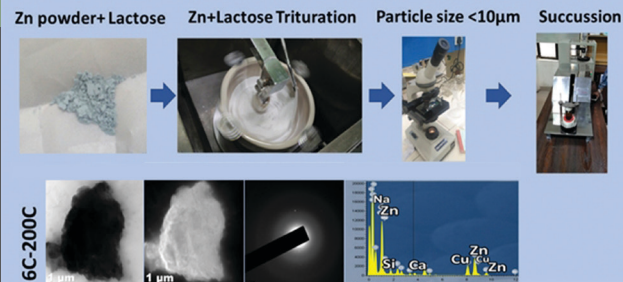
**Uniqueness of the Solution:** The team has limited the total number of dilutions within the Avogadro's number but retained the medicine potency succussion (vigorous mixing) to maintain the principle of homoeopathy preparation intact. They have shown that once the concentration after dilution reached a threshold of a few ng/mL, further serial dilutions did not result in a concentration reduction and an asymptote was formed. The manufacturing process indicates that the

silicate overcoat may also happen with all types of homoeopathic medicines by repeating succussion without excessive high dilutions.

**Current Status of Technology:** The team has tested the new method of homoeopathic medicine preparation at Willmar Schwabe India, a subsidiary of a German company. The company has accepted the process for industrial-scale manufacture, and this new method will be available to all manufacturers.

**Societal Impact:** In today's pandemic affected world, there appears to be a growing demand to cure various health conditions that elude any particular medicine system; it has made pluralism in therapeutic options a way of life. The Homoeopathy system has widespread support, cultural conformity, and many practitioners. The researchers have made efforts to develop new homoeopathic medicine potencies scientifically that are better in quality and improved efficacy

### HOMEOPATHIC MEDICINES Zincum Metallicum - Preparation by New method



of their biological effect. Their new medicine preparation methods could help dispel the controversies surrounding the nature of homoeopathic medicines in the scientific world.

**Patent(s):** Filed

**Relevant Industries:** Healthcare, Pharmaceuticals.

**Faculty:** Prof. Jayesh Bellare and Prof. A. K. Suresh, Chemical Engineering.

## One-stop Solution for Tinnitus Matching and Management



**Problem Statement:** Tinnitus (a constant ringing sound in the ear in the absence of an external source) can affect any gender and age group. Tinnitus is a serious medical condition; if untreated, it may lead to mental health conditions like anxiety, depression, sleep disturbance, and sometimes even suicidal attempts. In addition, the quality of life and work efficiency is affected in tinnitus patients. Therefore, precise tinnitus diagnosis and management are the main challenges for ENT doctors and audiologists. The researchers have developed an electronic device for managing tinnitus symptoms and helping to improve the quality of life in patients.

**Uniqueness of the Solution:** The one-stop tinnitus diagnosis and management is a unique single platform for doctors and patients. The tinnitus diagnosis device caters to the ENT doctors/audiologists in clinics and hospitals and tinnitus management software for tinnitus patients. The approximate cost

of a tinnitus matching device will be INR 25000- 30000 per device, and the tinnitus management software will be available to the patients on a monthly subscription basis.

**Current Status Technology:** The team has demonstrated an integrated pilot system. The tinnitus management device has passed the EMI/EMC as per IEC 60601-1-2 Medical device standard. The researchers have demonstrated the device and the tinnitus management protocol to 30 senior ENT surgeons from Maharashtra, and their response is encouraging. The device and software are now at the field testing stage.

**Societal Impact:** The integrated tinnitus management system can help manage tinnitus symptoms and improve the quality of life of the patients, thereby avoiding the mental and physical health issues caused by tinnitus. The estimated market potential for tinnitus diagnosis and management solutions in India is huge

due to the large population with tinnitus.

**Patent(s):** Filed

**Relevant Industries:** Medical Devices, Digital Health Management.

**Faculty:** Prof. Maryam Shojaei Baghini, Electrical Engineering.

# Peptide-based Test for Prognosis of SARS-CoV-2 Infection

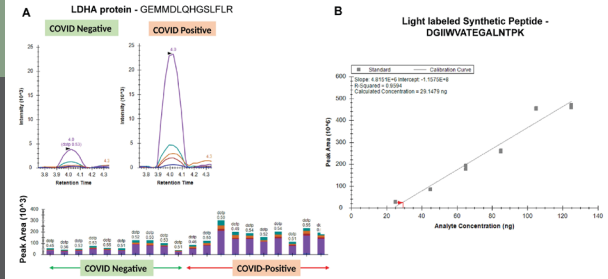
**Problem Statement:** The COVID-19 infections have been spreading at an alarming rate, and the severity of this outbreak remains unclear. Currently, RT-PCR is able to detect the infection; however, predicting the progression of disease severity in a patient remains a challenge. Knowing the severity and likely progression of the disease can help hospital management take timely action for cases that are likely to face severe disease progression. The researchers have addressed the need for the prediction of SARS-CoV-2 infection progression through their proposed peptide-based test using a technique called selected reaction monitoring (SRM) assay. Their method can help the hospital management process by identifying the risk level faced by patients who test positive for SARS-CoV-2.

**Uniqueness of the Solution:** The targeted SRM assays with the specific peptide-protein panel of COVID-19 severity biomarkers can predict the

progression of the disease. Thus the test gives more information than the widely used RT-PCR test. Currently, there are no similar products available in the market.

**Current Status of Technology:** The researchers have completed experimental proof of concept. They have also tested and validated their proposed method on patients' samples.

**Societal Impact:** Targeted SRM high-throughput assay is a rapid test. It can perform extensive scale screening of the samples and identify the more vulnerable patients. This test can also be used for the detection of other infections such as malaria and dengue in the COVID-19 infected patients and ensure proper direction of treatment. Therefore, the researchers envisage that the product will be in high demand in the global markets for the COVID-19 prognosis.



Targeted MRM based validation for the host peptide detected in the COVID-19 infected Swab samples.

**Patent(s):** Filed

**Relevant Industries:** Healthcare, Biotechnology, Medical Devices.

**Faculty:** Prof. Sanjeeva Srivastava, Biosciences & Bioengineering.



## Point of Care Device for Albumin and Creatinine

**Problem Statement:** Chronic kidney disease, pre-eclampsia (a complication during pregnancy) and acute kidney disease are prominent renal (relating to the kidney) diseases. Serum albumin and creatinine, which are indicators of renal health, need to be monitored in patients with these diseases. Medications for the treatment of cardiovascular ailments have a deteriorating effect on the kidney. Fifty-five million individuals suffer from cardiovascular ailments, and more than 10 million cases of chronic kidney disease are diagnosed each year in India. Many of these cases result in kidney failure, leading to a high mortality rate. Hence these patients also need a constant monitoring system for albumin and creatinine levels in the blood. These diseases can be avoided if diagnosed and treated early. Therefore, establishing a point-of-care device for detecting albumin and creatinine levels in the blood is the need of the hour. The researchers have addressed this requirement with a novel, compact and affordable device.

**Uniqueness of the Solution:** This point-of-care device has a metal-based detection for creatinine. It is a novel method for the detection of albumin and creatinine levels. It is more affordable than competitors' products and is also a compact solution.

**Current Status of Technology:** The researchers have completed designing the prototype and tested this product with small numbers of clinical samples. The researchers are in discussion with a company to licence this technology.

**Societal Impact:** The proposed point-of-care device for detecting albumin and creatinine levels in the blood is economical compared to the other commercially available devices. Hence, this device can be used in rural areas or as a budget-friendly option in the public health domain. The estimated cost of the meter is around INR 2000, while the strip used for a blood sample is estimated at INR 50 per test.



**Patent(s):** Filed

**Relevant Industries:** Healthcare, Medical Devices.

**Faculty:** Prof. Rohit Srivastava, Biosciences & Bioengineering.

## Point of Care Device for HbA1C

**Problem Statement:** HbA1c, glycated haemoglobin test indicates an average level of blood sugar over the past two to three months. Individuals with diabetes need this test regularly to see if their levels stay within range. The current cost of the point-of-care test in laboratories for HbA1c is around INR 200/- per test, which is expensive for the low socio-economic class in India. India has an estimated 77 million people with diabetes; thus, the Indian market needs an affordable test system to detect HbA1c. Lateral flow-based methods are simple and quick tests to determine the presence and amount of a substance in the sample. They work on urine, blood, saliva, sweat, serum, and other fluid samples. The researchers have designed a diagnostic device that uses the paper shunt technology in lateral flow assay based testing and addressed the problem of making HbA1c testing in India affordable, accessible and easy.

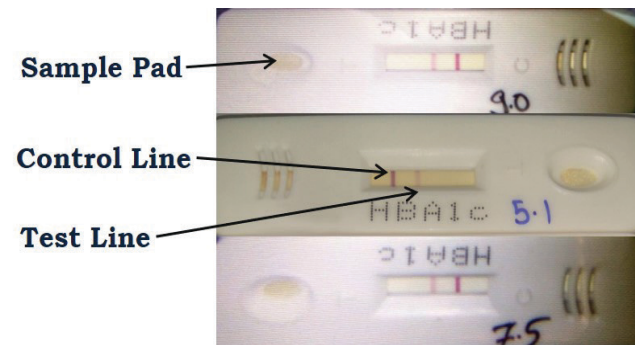
**Uniqueness of the Solution:** A shunt is

essentially a flexible tube, also popularly called a catheter. Such a shunt or a catheter has an inflow, a valve mechanism and an outflow to regulate the flow of the fluid. For instance, in treating hydrocephalus, a shunt is placed into the area of the brain where cerebrospinal fluid is produced. In this case, Paper shunt technology is used for making the lateral flow assay a more affordable point of care test for HbA1c by minimising the use of antibodies in the assay.

### **Current Status of Technology:**

The prototype development stage is complete; The researchers have performed a small-scale clinical study with blood samples.

**Societal Impact:** The proposed device for the detection of haemoglobin A1c is economical compared to the commercially available devices. The testing meter will cost approximately INR 2500, and each testing strip about INR 100 per test. Hence, this device is a



budget-friendly testing method even for the low-income group.

**Patent(s):** Filed

**Relevant Industries:** Healthcare, Medical Devices.

**Faculty:** Prof. Rohit Srivastava, Biosciences & Bioengineering.

## Point of Care Device for Total Cholesterol, Triglycerides and HDL Cholesterol

**Problem Statement:** Cholesterol, triglycerides, and high-density lipoproteins are important constituents of the lipid fraction of the human body. High cholesterol and triglyceride levels increase the risk of developing heart disease. Recent studies have reported high cholesterol levels in 25-30% of urban and 15-20% of rural subjects in India. Early detection, proper medication, and lifestyle changes can help maintain cholesterol levels, triglycerides, and high-density lipoproteins. The researchers have come up with an economical point of care device to measure the lipids and help to monitor the levels easily and in a budget-friendly way.

**Uniqueness of the Solution:** The researchers have made the colorimetric strip by immobilisation of the enzyme onto a paper surface by conjugation with polymer and specific surfactant solubilisation chemistry. This method is capable of determining free, bound HDL-C and LDL in blood without pre-

treatment for separation of RBCs. The meter's function is similar to a diabetes blood glucose meter and is easy to use. The user needs to insert the test strips into the electronic device, and it measures the amount of cholesterol automatically. The device quantifies total cholesterol, free and bound cholesterol along with high-density lipoprotein-cholesterol (HDL-C) and low-density lipoprotein (LDL) from blood.

**Current Status of Technology:** The product is in the clinical validation stage. The researchers have completed the prototype development and academic clinical validation.

**Societal Impact:** The point-of-care meter fabricated for the detection of cholesterol, triglycerides and high-density lipoproteins is economical compared to the commercially available devices. This device can be used in rural areas or any place as it is easy to use, like a glucometer.



**Patent(s):** Filed

**Relevant Industries:** Healthcare, Medical Devices.

**Faculty:** Prof. Rohit Srivastava, Biosciences & Bioengineering.

## Point of Care Microscopy Test for Sickle Cell Anaemia

**Problem Statement:** Sickle cell disease is a hereditary haemoglobin disorder that makes red blood cells (RBCs) stiff and sickle-shaped. A confirmed diagnosis to distinguish between patients with sickle cell anaemia (i.e., those with only sickle haemoglobin in their blood) and carriers (i.e., those born with both normal and sickle haemoglobin) requires haemoglobin electrophoresis or high-performance liquid chromatography (HPLC). However, extensive laboratory infrastructure and highly-trained personnel required to perform these tests are unavailable in most endemic regions, mainly in remote locations. Hence there is a strong need for a diagnostic test to replace HPLC (a widely used technique) in remote and rural areas with limited access to healthcare infrastructure.

**Uniqueness of the Solution:** The team has developed a first-of-its-kind microscopy-based test that can conclusively distinguish between sickle cell anaemia and the trait from only two

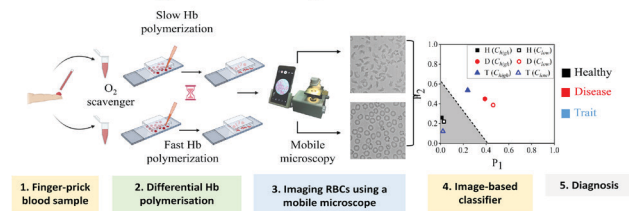
drops of blood in less than an hour with high accuracy, comparable to the HPLC method.

Blood samples collected from different individuals will show unique sickle-shaped cells if infected and are visible under the microscope, helping in classifying them as either healthy, trait or diseased. The classifier developed by the team can further give a confirmed diagnosis, with accuracies comparable to independently performed HPLC in pilot studies.

**Current Status of Technology:** The current prototype demonstration and/or pilot-scale system is validated in the relevant environment. The microscope is easy to transport and place in laboratories that are in remote locations with one trained microscope user.

**Societal Impact:** According to an ICMR survey, approximately 20% of children in India born with sickle cell anaemia will die by the age of two because of a delay in

Microscopy-based confirmed diagnosis of sickle cell disease in <60 min



diagnosis. Early diagnosis by counselling parents and awareness about sickle cell anaemia can help in disease management amongst susceptible children, reduce mortality and improve the quality of life. This microscope has already been used to test in different sickle cell screening camps organised at Valsad (Gujarat), Talasari (Maharashtra) and Nagpur (Maharashtra).

**Patent(s):** Filed

**Relevant Industries:** Healthcare.

**Faculty:** Prof. Debjani Paul, Biosciences & Bioengineering.

## Point-of-Care Device for Haemoglobin



**Problem Statement:** Every year ten to fifteen million new cases of anaemia are registered in India. The reason for it is primarily a result of poor diet and sedentary lifestyle. Haemoglobin levels in the blood is a critical factor for recovery from many diseases. In pregnant women, haemoglobin monitoring becomes necessary for tracking foetal and maternal health. Additionally, athletes also need to monitor their haemoglobin levels for optimum performance. Point-of-care tests for checking haemoglobin levels provide rapid results. Unlike conventional laboratory-based testing, rapid tests can be used at the time and place of patient care, which can help in further treatment. Timely detection of low haemoglobin levels thus becomes very crucial to take corrective action and improve a person's overall health. The researchers have addressed this need and developed an affordable point-of-care device for quantifying haemoglobin levels. The anaemic patients and pregnant women are key target consumers of this device.

**Uniqueness of the Solution:** This device is antibacterial, and ferrous cyanide is not used in its operation, thus making it safer for wider use. In addition, it is affordable and an easy-to-use portable point-of-care device with a digital reader.

**Current Status of Technology:** The prototype of the portable point-of-care device has been developed, and it is at TRL 3 stage. The researchers have also performed a small scale clinical study. In addition, they are in discussion with a company for licensing this technology.

**Societal Impact:** The point-of-care device developed for the detection of haemoglobin is economical compared to the commercially available devices. Hence, it can be a budget-friendly option everywhere, including rural areas. Furthermore, in the public health domain, the device can be used in primary health care centres for monitoring maternal and foetal health in a cost-effective way.

**Patent(s):** Filed

**Relevant Industries:** Healthcare, Medical devices.

**Faculty:** Prof. Rohit Srivastava, Biosciences & Bioengineering.

## Point-of-Care Device for Vitamin D3



**Problem Statement:** Vitamin D deficiency is mild to moderate or severe deficiency. In case of severe deficiency, various symptoms may be observed, including bone and muscle pain, muscle weakness, hip pain, fractures, difficulty walking, climbing stairs, and getting out of a chair. The early detection of Vitamin D3 levels aid in the prevention of severe deficiency. Epidemiologic studies allow the identification of risk factors for vitamin D deficiency such as ageing, being overweight, dark skin pigmentation, wearing covering clothes, or having a low level of outdoor activity. Vitamin D deficiency prevails in epidemic proportions all over the Indian subcontinent, with a prevalence of 70 –100% in the general Indian population. However, commercially available tests are costly. Lateral flow-based methods are simple and quick tests to determine the presence and amount of a substance in the sample. The researchers have designed a diagnostic device that uses the paper shunt technology in lateral flow

assay based testing and addressed the problem of making Vitamin D3 testing in India affordable and accessible.

**Uniqueness of the Solution:** A shunt is essentially a flexible tube, also popularly called a catheter. Such a shunt or a catheter has an inflow, a valve mechanism and an outflow to regulate the flow of the fluid. For instance, in treating hydrocephalus, a shunt is placed into the area of the brain where cerebrospinal fluid is produced. In this case, Paper shunt technology is used to make the lateral flow assay a more affordable point of care test for Vitamin D3 by minimising the use of antibodies in the assay.

**Current Status of Technology:** The prototype development stage is complete. The researchers have tested this product with a standard solution.

**Societal Impact:** The proposed device for detecting Vitamin D3 tries to make the testing affordable for everyone compared

to other available devices for the same. Hence, the device can be used in rural areas or any place and low-income groups.

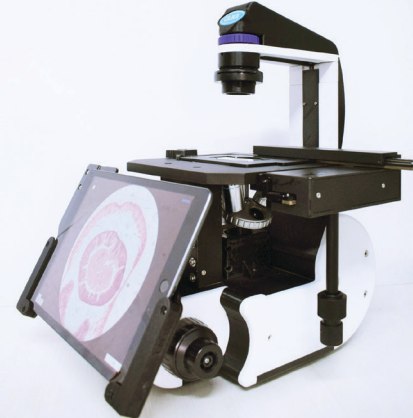
**Patent(s):** Filed

**Relevant Industries:** Healthcare, Medical Devices.

**Faculty:** Prof. Rohit Srivastava, Biosciences & Bioengineering.



## Portable Digital Inverted Microscopes



**Problem Statement:** Microscopes are the key pieces of equipment in most research institutes, academic sectors and diagnostic laboratories. Diagnostics or the pathology labs in 2-, 3-, or 4- tier cities serve as sample collection centres; however, immediate sample analysis and reporting the diagnosis results is a constraint as the laboratories lack microscopes. Currently, the labs transport the sample slides to larger diagnostic labs for analysis and await the reports, which delays treatment of emergency-case patients. Moreover, the probability of degradation of the sample during transport is high leading to difficulty in analysis. If Microscopes are available, labs could generate and capture diagnostic quality images and analyse the samples independently. The present research has addressed this lack by developing a portable microscope unit.

**Uniqueness of the Solution:** The Portable Digital Inverted Microscope comprises two lines of battery-operated,

portable, brightfield microscopes (single and variable magnification) fitted with digital displays. These microscopes have a compact, ergonomic design. They can capture, store and transmit high-resolution colour images and videos that can be directly projected onto a screen using an HDMI connector. The set-up allows real-time interaction with research collaborators or demonstrating to a class during image or video capture. The digital display (mobile phone or iPad) can be removed from the microscope when not in use. As these are inverted microscopes, they can image slides and liquid samples. Internal optical and mechanical designs are optimised for image quality and stability of the sample.

**Current Status of Technology:** The prototype of the Portable Digital Inverted Microscopes is ready for deployment.

**Societal Impact:** These microscopes are suitable for pathology labs (especially IVF labs handling liquid samples) in 2-, 3-, or

4- tier cities and for teaching and research institutes. This line of microscopes addresses the need for good quality inverted microscopes in many research and diagnostic labs in India, as well as for field-based studies.

**Patent(s):** Filed

**Relevant Industries:** Healthcare, Digital Care Devices.

**Faculty:** Prof. Debjani Paul, Biosciences & Bioengineering.

## Scalable Continuous Flow Synthesis of Pharmaceuticals and Agrochemicals



**Problem Statement:** At present, India's pharmaceutical and agrochemical industry does not synthesise valuable oxazole compounds using the continuous flow method. The continuous flow methodology will help industries produce different heterocycles on the bulk scale in a safer manner, which will be cost-effective and strengthen industrial productivity. Synthesis of oxazole based pharmaceuticals, agrochemicals and natural products have been previously reported by using transition metal protocol under high temperature. These methodologies suffer from poor yield along with ketazines formation as a byproduct. Safety and scalability are two major concerns to date. Overcoming these limitations, researchers at IIT Bombay have streamlined the strategy for the synthesis of oxazole-based pharmaceuticals, agrochemicals and natural products by continuous flow method.

**Uniqueness of the Solution:** This project deals with the development of methodology using continuous flow reactors where the reaction will occur in micro-channels in the presence of visible light and mass transfer among the molecules giving a short reaction time. Fully optimised flow reactor methodology is used to prepare the complex oxazole compounds on a kilogram scale with minimal post-synthetic work-up, unlike batch processes.

**Current Status of Technology:** Researchers have designed a prototype assembling flow reactors and successfully synthesised oxazole molecules containing both aromatic and aliphatic donor-acceptor/acceptor-acceptor diazo carbonyl or diazoacetate compound with readily available nitrile source.

**Societal Impact:** Targeting a novel pathway that controls fat circulation in

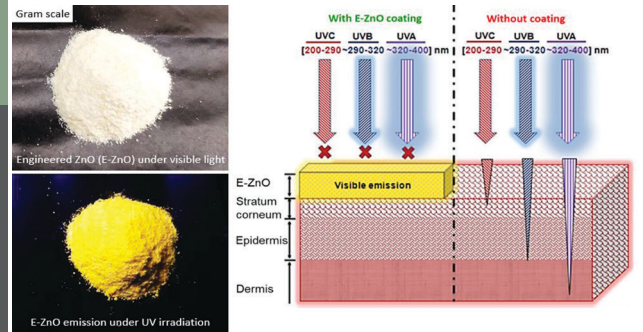
blood could help us control the epidemic of obesity, diabetes and accompanying maladies.

**Patent(s):** In progress

**Relevant Industries:** Pharma and Agrochemical industries.

**Faculty:** Prof. Debabrata Maiti and Prof. Arnab Dutta, Chemistry.

## Shiny Skin™: A Transparent Multifunctional Sunscreen



**Problem Statement:** Rapid ozone layer depletion has expedited the increase in skin cancer in recent times. Skincare products viz. sunscreen lotions help prevent skin cancer and allied skin disorders while also enriching the aesthetic appeal of the skin and rendering the skin wrinkle-free. The researchers came up with a solution that achieves these goals through a novel and multifunctional defect engineered ZnO (E-ZnO) based ultraviolet radiation (UVR) filter that acts as an active ingredient for skincare products.

**Uniqueness of the Solution:** This innovative solution highlights the potential of E-ZnO as a safe and multifunctional UV filter for skincare. E-ZnO is UVR absorbent and exhibits properties of excellent photostability (>4 hrs) enriched by its unique surface chemistry and has high molar absorptivity and broadband UVR attenuation (400 nm to 250 nm). In addition, it has visible emission matching human in vivo skin emission

colour that provide desired skin sensorial properties. In vitro evaluation also shows biocompatibility and antioxidant potential that mitigates skin oxidative stress, thereby minimising the risk of skin cancer. Since it is a patented technology, there are no products of similar property available currently.

### **Current Status of Technology:**

Researchers have achieved ideation, feasibility check, validation, and proof of concept. They have accomplished automation and developed the technology; the next step is to achieve an industrial scale of production and test the product in a relevant environment.

**Societal Impact:** The use of E-ZnO as a multifunctional UVR absorbent is cost-effective, scalable for large-scale production and can achieve maximum health security pertaining to skin melanoma and related skin diseases. Persons working in the construction sector are typically more prone to

occupational skin melanoma, but most labourers cannot afford the expensive treatment. Therefore, the researchers envisage indigenous production of nanotechnology-based sunscreen products that populations below the poverty level can use to help prevent skin cancers.

**Patent(s):** Filed & Granted

**Relevant Industries:** Sunscreen, Pharmaceutical, Cosmetics, Materials.

**Faculty:** Prof. Ajit Kulkarni, Metallurgical Engineering & Materials Science.

## Single and Two-Column Oxygen Concentrators



**Problem Statement:** The severity of COVID-19 and its impact on people's livelihood created a huge opportunity for indigenously made oxygen concentrators (OCs). The researchers have developed affordable single and two-column OCs to help reduce the load on hospitals for mild symptomatic patients who do not require the high flow rate oxygen therapy or ventilators. This technology can also address oxygen requirements for patients with respiratory diseases who are highly affected by the deteriorating air quality in metropolitan cities.

**Uniqueness of the solution:** Oxygen enriched air based on the PSA (Pressure swing adsorption) technology is produced using zeolite material (Nitroxyl/LiLSX) and can be used for patients at homes and hospitals. For a single column machine, the amount of zeolite reduces by almost 50% compared to two-column systems. This invention relates to a unique thermodynamic cycle that reduces the necessity of actuators (solenoid valves)

by more than one for a two-column and two in a single column system. This technology reduces the burden of electronic waste and the amount of zeolite needed for the same oxygen flow rate. It also makes the machine more reliable due to fewer actuators and produces OCs in large quantities at an affordable cost.

**Current Status of Technology:**

The researchers have observed and formulated the technological concept of this machine well. Two machines called two-column and single column systems have been developed in the lab environment and validated for the required performance. The technology has been licensed to industry under IIT Bombay's licensing policy. IIT Bombay and the company involved have signed an MoU between them.

**Societal Impact:** The PSA technology to generate oxygen is very important for Indian society due to the severity of

the COVID-19 pandemic and worsening air quality in metropolitan cities. This technology can drive indigenously developed OCs and be an alternative to the expensive imported OCs that dominate the Indian market. It can generate employment, provide affordable oxygen therapy to patients at homes and hospitals and reduce the mortality rate due to its unavailability in suburban and remote areas.

**Patent(s):** Under progress

**Relevant Industries:** Healthcare, Thermodynamics, Cylinder.

**Faculty:** Prof. Sudarshan Kumar, Aerospace Engineering.

## Small Animal Cerebral Blood Flow Imaging Platform

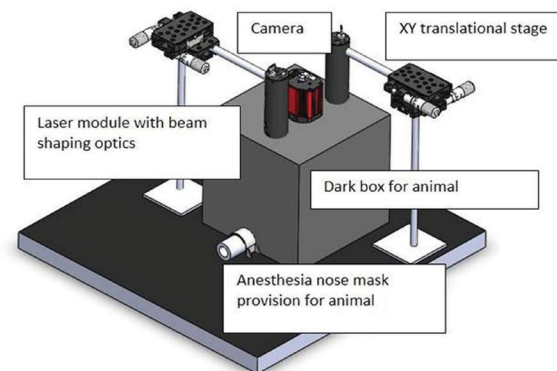
**Problem Statement:** The researchers have developed a small animal cerebral blood flow (CBF) imaging platform based on Multi speckle diffuse correlation spectroscopy (M-DCS) that they developed in-house at IIT Bombay. The system comprises a laser with necessary scanning optics to scan the brain and a camera to capture intensity speckles which are then post-processed to get 2-D and 3-D cerebral blood flow distributions. Employing a camera for DCS gives a very cost-effective and compact deep tissue imaging system by allowing high-density parallel detection of several speckles. The team envisages developing the necessary algorithm to visualise the CBF as an image and its quantified flow. The potential use of the system can be to monitor the effect of a drug on post-stroke reperfusion or functional activation studies in small animal models.

**Uniqueness of the Solution:** The system is based on a new method developed in the lab called Multi speckle diffuse

correlation spectroscopy (M-DCS). The researchers have already published the proof of concept. Their work is the first indigenous attempt to develop a small animal imaging platform focused on cerebral blood flow. Currently, no national players are present, except laser speckle imaging systems which differ from what the solution proposes.

**Current Status of Technology:** The proof of concept is achieved and published. The researchers have deployed and tested the system in the relevant environment (in mice). They have identified the needed components to build the system with an approximate budget.

**Societal Impact:** Diseases like Parkinson's, Alzheimer's and stroke are increasing in India, prompting necessary drug developments. The proposed platform can be a low cost and compact solution for preclinical studies towards this purpose. The researchers are also



scaling this technology to adapt it for longitudinal bedside monitoring of cerebral blood flow in human patients. The low-cost technology can also boost research work for drug discovery/testing and functional activation/cognitive studies in academia and industry.

**Patent(s):** Filed

**Relevant Industries:** Healthcare; Digital Health Monitoring, Research.

**Faculty:** Prof. Hari M Varma, Biosciences & Bioengineering.

## Sodium and Potassium ElectroFinder



**Problem Statement:** The biochemistry sector is one of the fastest-growing sectors in the Indian in-vitro diagnostics (IVD) industry. Currently, the biochemistry auto-analysers are the backbone of major diagnostic chains in the country. Biochemistry analysers are used in all laboratories, from small PoC to high-throughput clinical labs, to test analytes such as proteins, enzymes, and electrolytes. Benchtop analysers are the most common type, but compact bedside models, usually with fewer test options, and high-throughput floor-based units are also available. A few major multinational companies dominate the biochemistry market in India. Manufacturers are developing analysers with low volume reagent consumption. This work by researchers handles the design and development of a Blood Electrolyte quantification device for human blood samples and assays for the same. The researchers have developed a technology to make the blood test for sodium and potassium rapid and cost-effective using a compact instrument.

**Uniqueness of the Solution:** The researchers have developed a point-of-care optical reader to quantify liquid-based sodium and potassium assays. This optical reader is implemented on the principle of absorbance and scattering of light in liquid solutions. The researchers implemented the electronic architecture of the reader from the breadboard level to the printed circuit board level in order to miniaturise the optical reader. The device utilises the principles of turbidimetry and nephelometry to quantify the electrolyte present in the sample.

**Current Status of Technology:** The researchers have completed building the prototype. The product is also tested with a large number of clinical samples at the KEM Hospital, Mumbai.

**Societal Impact:** The proposed technology will decrease the cost of sodium and potassium blood tests by 50 INR per test. Also, it needs only 10 $\mu$ l of serum sample and 60 seconds per test

to reduce the turnaround time per test, which is useful in facilities with limited resources like primary health centres, ambulance services, disaster sites and rural healthcare centres.

**Patent(s):** Filed

**Relevant Industries:** Healthcare, Medical Devices, Digital Health Monitoring.

**Faculty:** Prof. Rohit Srivastava, Biosciences & Bioengineering.



## Thin-Film Silicon Piezoresistive Pressure Sensor

**Problem Statement:** India has the second-largest number of diabetic patients globally (82 million). Diabetic patients develop peripheral neuropathy characterised by loss of sensation in the feet, due to which they have abnormally high-pressure points ( $>750\text{kPa}$ ) under the feet. The skin gets thickened (called callus) in these areas, forming an ulcer even with a minor injury. Chronic ulcers can lead to amputation of a toe or foot. Timely identification and regular monitoring of high-pressure points of feet are highly critical in mitigating this problem. The researchers have proposed a thin film piezoresistive pressure sensor for checking foot pressure.

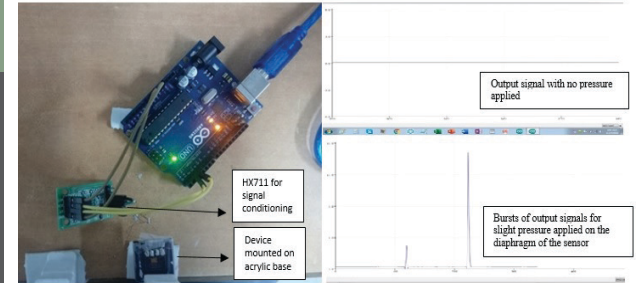
**Uniqueness of the Solution:** Aluminium induced crystallisation (AIC) allows the fabrication of microcrystalline silicon on flexible substrates like polyimide at temperatures less than  $400^\circ\text{C}$ , greatly reducing the fabrication cost. Polyimide is also used as a diaphragm material, removing the micromachining step.

Silicon as a sensing material offers robustness, long-time stability, and easy integration with CMOS technology for readout circuitry. The piezoresistive pressure sensor can also be applied wherever sensitive pressure sensing is needed, such as in robotics, automobile and aviation sectors.

### Current Status of Technology:

Experimental proof of concept is ready, and the researchers have demonstrated the use of this technology with a colour code map showing variation in pressure application. They have also performed component and breadboard validation of pressure sensors in a laboratory environment.

**Societal Impact:** Limb amputation leads to pain, loss of productivity and social role, unemployment, increased dependency of patients and also leads to stigma due to distorted body image. Such cases generally occur among rural or poor urban populations who fail to



notice or monitor foot ulcers due to lack of sensation. As a result, they get infected and then approach for treatment. Such a population needs more affordable diagnostic solutions, which is one of the highlights of this technology. Most of the current pressure sensing platforms are imported and costly. The proposed technology is cost-effective and highly relevant for the Indian population.

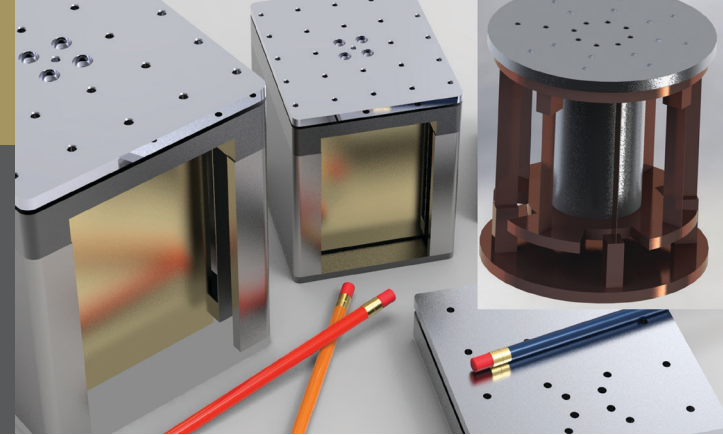
**Patent(s):** Nil

**Relevant Industries:** Healthcare, Medical Devices.

**Faculty:** Prof. Rajiv O. Dusane, Metallurgical Engineering & Materials Science.

**Manufacturing (including smart, advanced and industry 4.0)**

## Compliant Mechanisms for Ultra-Precision Linear and Rotary Motion Control



**Problem Statement:** As technology advances, its application in specific domains like aerospace and defence also need critical systems. Further, in the manufacturing industry too, micro-3D printing and micro-milling are upcoming technologies that fuel research at the microscale to translate into devices beneficial for society. The micro-nanopositioning of critical optical systems is one such application. Ultra-high-precision positioning in the nanometric accuracy levels is infeasible with conventional ball guided stages because of friction. The use of piezo actuators limits the travel range. The magnetic levitation-based stages are expensive and energy-intensive and need to be imported. Thus, researchers at IIT Bombay are exploring compliant robots for high-speed, lightweight applications. The proposed compliant mechanism technology can be futuristic in this domain.

**Uniqueness of the Solution:** The

proposed innovative solution uses compliant mechanisms and their variants. Compliant mechanisms are inherently friction-free, backlash-free and need no lubricants. There is no wear and tear and maintenance with frictionless motion, and calibration is less frequent. The products thus promise long life with a high degree of reliability. The challenges posed are in terms of parasitic errors, fabrication, mechatronics and control. These have been resolved using the research work done during the development of this technology.

**Current Status of Technology:**

Several systems and prototypes for multiple applications (micro 3D printing, micro-milling, micro UTM) has been developed based on this technology and tested in the laboratory successfully.

**Societal Impact:** A part of the technology has been licensed to two companies, and one of them received a prestigious FIE Foundation award at IMTEX 2019.

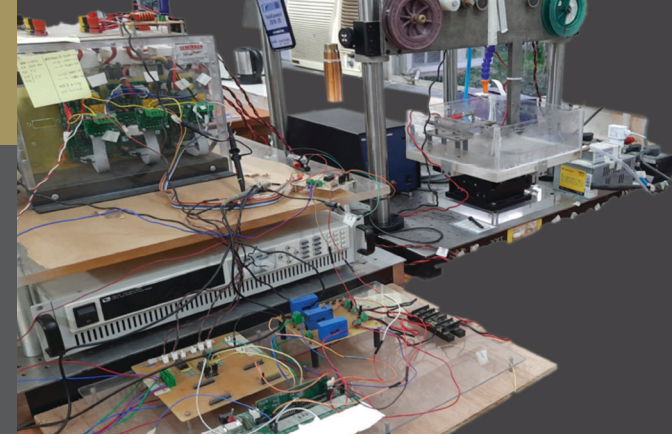
The group founded a startup company Flexmotion Technologies for better translation into commercial products.

**Patent(s):** Filed and Granted

**Relevant Industries:** Defence, Aerospace, Robotics, Manufacturing, Semiconductor Equipments.

**Faculty:** Prof. Prasanna Gandhi, Mechanical Engineering.

## Customizable Miniature Wire EDM



**Problem Statement:** Indian MSME sector (plastic die makers, makers of watch parts, makers of small parts for medical equipment, etc.) depends on specialised machining shops' machinery for high precision cutting and complicated geometries out of metallic blocks. These factors add to the time and money involved in manufacturing. Moreover, commercial machines are large in size: they usually occupy an area of 10 ft × 10 ft × 10 ft. In addition, they are very costly and mostly imported outside India. The cost ranges from INR 20 lakhs to 2 crores for importing them. Therefore, many MSME level industries depend on specialised wire EDM shops to get their jobs done. The wire EDM is the workhorse of precision manufacturing. However, the commercial machines lack customizability – therefore, they cannot be used by research/educational institutes – which require that the wire EDM machines be tweaked easily. The Customisable Miniature - wire electric discharge machining (EDM) proposed by

the IIT Bombay research team can solve these issues and help boost the local MSME sector.

**Uniqueness of the Solution:** The machines presently available in the market require a three-phase power supply, plus they occupy a large size besides being very costly. The machine developed at IIT Bombay is plug and play type, which is smaller in size and is also affordable. It requires only a single-phase power supply for its operation.

**Current Status of Technology:** Component Laboratory Validated. Wire EDM is a highly complex system consisting of multiple components/subsystems. All the subsystems are assembled, and the machine is tested in the lab for cutting silicon and aluminium workpieces.

**Societal Impact:** The wire EDM will boost local manufacturing as it is small in size and affordable. Further, it can be

purchased easily by technical educational institutes like ITI, small engineering colleges, technical training institutes and various R&D setups.

**Patent(s):** Filed

**Relevant Industries:** Manufacturing, Biomedical, Plastic mould making.

**Faculty:** Prof. S. V. Kulkarni and Prof. Himanshu Bahirat, Electrical Engineering; Prof. Suhas S. Joshi, Mechanical Engineering.

## Deposition of Silicon Nitride Thin Films Using Hot-wire Chemical Vapour Deposition (HWCVD)

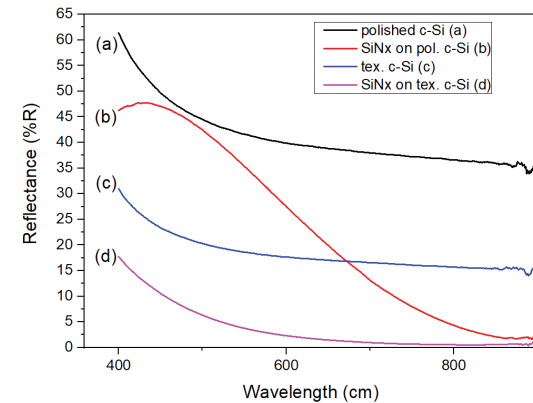
**Problem Statement:** Various industries such as energy, optoelectronics, MEMS, biomedical, ICs, etc., are becoming the principal technology development sectors in the Fourth Industrial Revolution (Industry 4.0). It is due to an immense focus on technology integration in developing materials, multidisciplinary systems, and hetero-devices to further enhance the scope of industrial applications. Silicon nitride constitutes one such material that is being explored with intense R&D for its optical and material properties, with applications in numerous industries. These applications include SiN films used as an insulator layer in Field Effect Transistors (FETs), a buffer/ capping layer in optoelectronics, and antireflective coating (ARC) in solar cells.

**Uniqueness of the Solution:** The team has employed the Hot-wire (or Cat.) CVD technique to deposit the a-SiN:H films on both polished and textured c-Si. The precursor gases used are silane (SiH<sub>4</sub>),

ammonia (NH<sub>3</sub>), and nitrogen (N<sub>2</sub>). This method allows for the deposition of silicon nitride films with tunable optical and material properties by varying deposition parameters: precursor gas ratio; deposition pressure; deposited a-SiN:H film; and the low substrate temperature (150-200°C). The HWCVD allows for the deposition of the films in a broader spectrum of base materials.

**Current Status of Technology:** Prototype of 80nm a-SiN:H ARCs with refractive index (RI) ~1.8 exhibiting an excellent reflectance of 1.7 % at 632 nm wavelength has been achieved on textured c-Si. To test the tunability of the deposited a-SiN:H, films with RI ranging from 1.8 to 3.5 and tensile stress running within ± 6 GPa have been fabricated.

**Societal Impact:** Apart from application in solar cells, silicon nitride ARCs are also used in corrective lenses to reduce glare for the wearer. It is also used on camera lenses for some components used for



optical experiments with lasers. The prospects offered by HWCVD to deposit a-SiN:H films permit the fabrication of application-specific films that can be used in optoelectronic devices and FETs.

**Patent(s):** Nil

**Relevant Industries:** Energy, Renewables.

**Faculty:** Prof. Rajiv O. Dusane, Metallurgical Engineering & Materials Science.

## Development and Evaluation of Indigenous Anti-Hail Guns

**Problem Statement:** Himachal Pradesh (H.P.), known as the fruit basket of India, has a variety of fruits and vegetables. However, many crops are damaged every year, as this area comes in a heavy hailstorm zone. So the researchers have indigenously designed an anti-hail gun to stop/minimise the effects of hailstorms, protect the crops, and maintain the quality of the crop.

**Uniqueness of the solution:** Strong shock waves sent through the anti-hail gun reach up and mix the positive and negative charges of the clouds, creating a neutralised zone within the cloud. This prevents the cyclic movement of water droplets and eventually prevents the formation of hails by stopping the droplets from freezing. The gun operates on LPG, making it cost-effective and eco-friendly compared to other gases. The maintenance cost is also low. The few imported anti-hail guns currently operating in an upper area of H.P. are costly, costing around INR 70 lakhs to

1 crore (including import charges). The proposed indigenous anti-hail gun will cost approximately INR 15 lakhs.

**Current Status of Technology:** The researchers created a prototype of an Anti-Hail Gun at the IIT Bombay Aerospace department Lab. A fully functional anti-hail gun, made on a larger scale, is installed at Krishi Vigyan Kendra, Kandaghat, District Solan (H.P.). Experimental data is being captured, and several parameters have been changed to improve its efficiency to generate a strong shock wave at a minimum fuel/air mixture and to minimise the pollutants.

**Societal Impact:** The anti-hail gun helps farmers protect their crops from hail damage and save much money as it can cover a large area. The development of the anti-hail gun will also generate employment for the local people and the industry, helping to generate revenue through export. Currently, farmers use plastic anti-hail nets as a hail protecting



method, but they are costly and harmful to the environment due to the use of plastic. The new anti-hail gun will be a cost-effective alternative for hail protection methods. The product will be in high demand in H.P. and Jammu & Kashmir region.

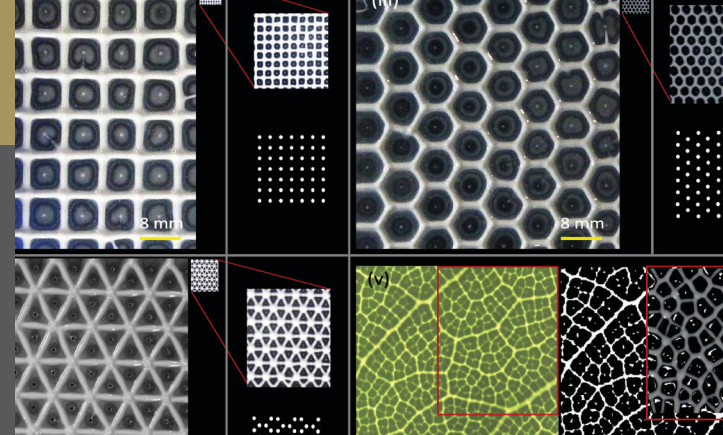
**Patent(s):** In progress

**Relevant Industries:** Manufacturing, Aerospace, Environment.

**Faculty:** Prof. Sudarshan Kumar, Aerospace Engineering.



## Multiport Controlled Hele-Shaw Cells for Multi-Scale Manufacturing



**Problem Statement:** The existing method for developing patterns using Hele-Shaw cell of micron/nanometer-sized particles of various materials such as minerals/oxides/sulphides/metals/ceramics may disclose the use of a steadily expanding liquid-liquid interface. The interface may be populated using a suitable surfactant molecule that may spontaneously organise into superstructures. These superstructures may vary over large length scales. However, such a method may enable pattern formation without control over neither initiation nor evolution of various features being formed by the displacing or displaced fluid. Further, the existing techniques like lithography can only fabricate the 2D structures. Thus, researchers at IIT Bombay are working on addressing this need through lithography-less fabrication. Lithographyless fabrication of a class of structures (fractal geometry, regular array, large triple point boundary islands) at multiple scales (submicron to 300  $\mu$ m).

**Uniqueness of the Solution:** The proposed solution is a complete out-of-the-box solution for this multiscale fabrication. Starting with viscous fluid sandwiched between two plates (Hele-Shaw Cell), it is based on novel control over the Saffman Taylor instability that occurs when plates are separated. Control is exercised by providing seed locations on the cell plates creating preferential pathways for the fluid structures to grow in the desired patterns.

**Current Status of Technology:** Several systems and prototypes for multiple scales have been developed based on this technology and tested in the laboratory successfully.

**Societal Impact:** The proposed technology has applications in the energy and healthcare sector. Large triple point boundary island structures are being explored in the energy sector for efficient hydrogen production. Future growth of clean, efficient hydrogen production is

crucial for the energy sector. In healthcare application development of whole blood plasma separator with high yield from heel prick volume 30 microliter blood is in advance stage of research.

**Patent(s):** Filed and Granted

**Relevant Industries:** Healthcare, Medical Devices, Clean Energy

**Faculty:** Prof. Prasanna Gandhi, Mechanical Engineering.

## Multi-wire EDM for Slicing Semiconductor Ingots

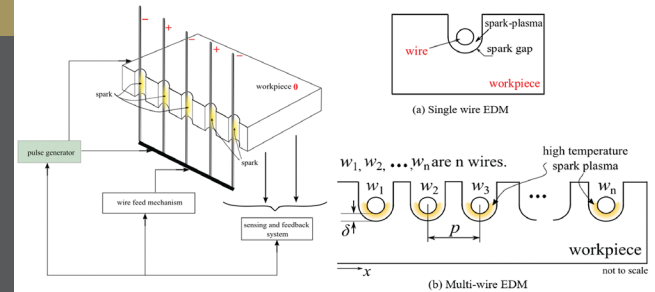
**Problem Statement:** Semiconductor wafers are ultra-thin plates (120-250 microns thick) of semiconductors used to make solar cells or integrated circuit (IC) components. It is proven that wire electric discharge machining (wire EDM or WEDM) can reduce the material loss from 40%, in the conventional wire-sawing technique, to 15%. However, one of the main problems in the practical realisation of multi-wire electric discharge machines (EDM) is the requirement of very high tension - 85-90% of the failure strength of wires. More tension makes multi-wire EDM susceptible to wire-breakage problems, and lesser tension reduces cutting accuracy with multi-wire EDM. Therefore, the problem is to reduce wire-tension-requirement without losing cutting accuracy.

**Uniqueness of the Solution:** To this end, two electrical supply schemes are proposed for multi-wire EDM, such that the wire-wire forces and hence the required tension is reduced to 20-30%

of the tension required with the present scheme. The current innovation proposes novel electrical supply schemes, such that the tension requirement in multi-wire EDM is reduced without sacrificing the machining accuracy. The schemes are unique because all the earlier solutions for the problem were structural in nature. Therefore, they were amenable to wear and tear besides ageing. Therefore, this is a preventive measure to the problem of wire-tension-requirement as against the remedial nature of solutions proposed to date.

**Current Status of Technology:** Proof-of-concept demonstrated analytically. The force computations are done by employing the proposed schemes. It is shown that the tension-requirement in the multi-wire EDM reduces to 20-40% to that of the tension required in the present schemes.

**Societal Impact:** The multi-wire EDM has the potential to establish a starting



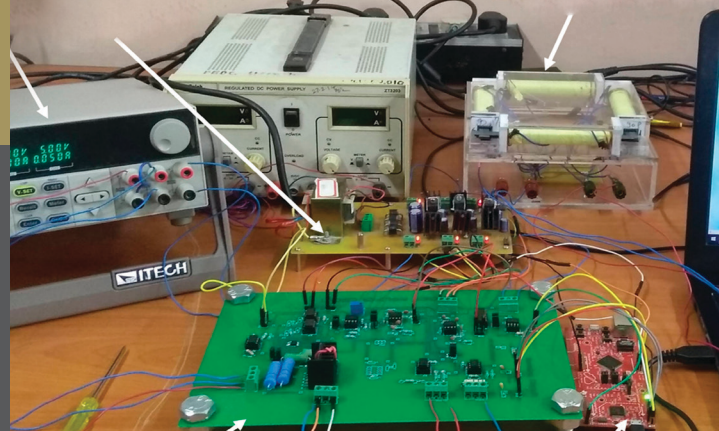
point for indigenous semiconductor manufacturing in India.

**Patent(s):** Filed

**Relevant Industries:** Electric Power, Manufacturing, Semiconductor Fabrication, Solar Photovoltaics, Metal Manufacturing, Sputtering Industry, Magnet Manufacturing.

**Faculty:** Prof. S. V. Kulkarni and Prof. Himanshu Bahirat, Electrical Engineering; Prof. Suhas S. Joshi, Mechanical Engineering.

## Novel Cost-Effective Magnetic Characterization Tool for Soft Magnetic Materials Used in Electrical Machines



**Problem Statement:** Soft magnetic materials used in electrical machines and equipment exhibit nonlinear and hysteretic behaviour during their magnetisation process. The loss behaviour of these materials depends on the excitation waveform, direction of magnetic excitation and other operating conditions. Commercial systems use expensive power amplifiers and data acquisition (DAQ) cards. Also, the standard Epstein bridge, which is popularly used to characterise soft magnetic laminations, requires higher voltages at higher frequencies. Thus, the researchers at IIT Bombay have attempted to design a flexible and cost-effective digital characterisation tool for measuring hysteresis characteristics and loss in the soft magnetic material. The voltage requirements at higher frequencies are reduced by designing a new Epstein bridge with smaller dimensions and a lesser number of turns.

**Uniqueness of the Solution:** Among the

key novelties of the work is the design and fabrication of a low-cost amplifier circuit along with a small Epstein bridge, which can be used to measure losses for a frequency range of 200–500 Hz. In addition, a loss separation algorithm is implemented in the LabVIEW based characterisation tool for the first time. This feature is used to predict the losses beyond the frequency range of the setup. The proposed tool is also capable of characterising soft magnetic materials for arbitrary flux density waveforms with harmonics. The designed setup is cost-effective compared to the existing tools in the literature and commercial magnetic characterisation systems available in the market.

### **Current Status of Technology:**

Technology validated in the laboratory environment.

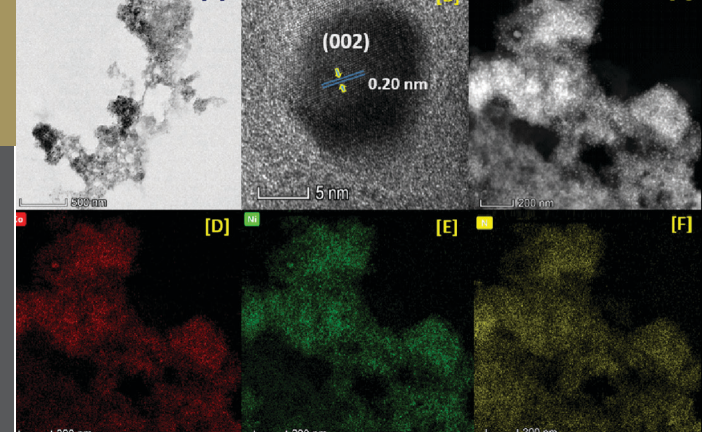
**Societal Impact:** The development of this tool indigenously would greatly aid in import substitution for niche applications.

**Patent(s):** Filed

**Relevant Industries:** Transformers, Electrical, Steel.

**Faculty:** Prof. S. V. Kulkarni, Electrical Engineering.

## Selective hydrogenation using 3d-transition metals



**Problem Statement:** Selective hydrogenations are very important reactions in organic synthetic chemistry. The procedure is a key method for synthesising valuable intermediates in pharmaceutical, polymer, fine chemicals industries and biomass valorisation processes. The advantage of selective hydrogenation includes avoiding the possible side product formation and elimination of impurities. Traditionally, hydrogenation is accomplished by using precious-metal-based catalysts such as Pt, Pd, Ru, Rh, Ir and Os in both homogeneous and heterogeneous ways. However, though efficient for hydrogenation, these catalytic methods have drawbacks such as the use of expensive precursors, toxic metal as active metal centres for hydrogenation, disposal issues after completion of the reaction, handling complications, and pyrophoric nature of the catalyst.

**Uniqueness of the Solution:** The present invention relates to hydrogenation

catalysts for cost-effective, simple and selective hydrogenation of  $\alpha,\beta$ -unsaturated carbonyl compounds and nitroarenes. The present invention, in particular, relates to hydrogenation catalysts such as Cobalt-Nickel bimetallic nanocatalyst supported on g-C<sub>3</sub>N<sub>4</sub> for selective hydrogenation of  $\alpha,\beta$ -unsaturated carbonyl compounds and nitroarenes under mild reaction conditions. The present invention also further relates to the preparation of Cobalt-Nickel bimetallic nanocatalyst supported on g-C<sub>3</sub>N<sub>4</sub>.

**Current Status of Technology:** A proof of concept and several examples are successfully tested in the lab.

**Societal Impact:** The cost of the product decreases significantly, and heavy metals usage would also come down. Further, disposal issues after completion of the reaction are also more minor.

**Patent(s):** In progress.

**Relevant Industries:** Pharmaceutical Companies and Petrochemical Industries.

**Faculty:** Prof. Leela Srinivas Panchakarla and Prof. Santosh J. Gharpure, Chemistry.

## Smart IoT Device



**Problem Statement:** A machine or structure is subjected to various factors that could affect the system's integrity or efficiency over time. Even the slightest deviation in the optimum working parameters could affect the health of the system leading it to get damaged or fail in the future. Detecting the origin of the fault before it has caused considerable damage will help prevent catastrophic machine failure. Of late, techniques of AI and Machine Learning are being applied to develop intelligent product development environments. Contemporary Manufacturing Engineering integrates multi-disciplinary concepts from Computational Science, Material Science, Mechanics, Thermal Science, Artificial Intelligence, Optimization and Data Science for a complete Product Development from inception through in-service. Thus, the researchers at IIT Bombay are developing a 'Smart IoT Device' as a self-contained IoT device capable of sensing various physical quantities and performing limited onboard

analytics.

**Uniqueness of the Solution:** Even though IoT devices that measure external and internal parameters are available in the market today, a device that does continuous data sensing and performs onboard analytics is very rare. Moreover, the combination of onboard analytics and cloud AI gives this device an unparalleled edge over other such solutions. The Smart IoT Device is integrated with the following sensors: Accelerometer, Gyroscope, AC-current, AC-voltage, temperature, humidity, light/IR light, and magnetic field sensors.

**Current Status of Technology:** A limited set of devices has been demonstrated in the actual shop floor environment.

**Societal Impact:** Machinery in industries gives many telltale signs of its health condition and potential failure. Sensing these telltale signs and predicting when the machinery would fail in the future will

have a direct effect on machine uptime and the cost of maintenance. Therefore, the device has immense applications in the smart manufacturing sector.

**Patent(s):** Nil

**Relevant Industries:** Manufacturing, IT.

**Faculty:** Prof. Asim Tewari, Mechanical Engineering.



## Ultra High-speed Micromachining Center



**Problem Statement:** Microscale feature creation using micro-milling/drilling is used in lithography masks, micro-moulds, micro-needle arrays for drug delivery, microfluidics, miniature heat-exchangers, etc. These features use microscale tools (25-500  $\mu\text{m}$  diameters) with limited flexural stiffness, which can be overcome by using ultra-high spindle speeds (>100,000 rpm). However, due to the lack of technical know-how and prohibitively expensive solutions offered by German companies, there is very low penetration of this technology in India. The researchers at IIT Bombay hope to bridge this gap by providing ultra-high-speed technology solutions in the form of precision high-speed micromachining centres and fabrication services to the Indian industry and strategic sector.

**Uniqueness of the Solution:** The technology provides science-enabled solutions for various challenging applications pertaining to micro manufacturing. The developed system

is the first of its kind in the country. The machine has been engineered for minimal vibration, and chatter-induced tool failure has been addressed via predictive stability modelling. The developed Ultra High-speed Micromachining Centre can compete with state-of-art German and Singaporean systems and will boost the global competitiveness of the Indian industry in the micromanufacturing domain.

**Current Status of Technology:** The first system developed at IIT Bombay has been working for the last ten years, which shows its robustness and durability. In addition, two fully functional high-speed machining centres were recently supplied to IIT Bhilai and BITS Pilani, Hyderabad.

**Societal Impact:** Currently, the world is rapidly moving towards miniaturisation. The technology has the potential to create a vibrant micro manufacturing ecosystem in India and catalyse machine development and micro-manufacturing

services in the country; it can boost employment in the country.

**Patent(s):** Filed

**Relevant Industries:** Micromachining, Lithography Masks, Biomedical Implants, Jewellery, Micro Moulding, Defence.

**Faculty:** Prof. Ramesh Kumar Singh, Mechanical Engineering.



**Robotics, Sensors & Actuators, and Semiconductors**

## Gallium Nitride Technology for RF Power Applications

**Problem Statement:** A semiconductor device platform capable of high speed and high power handling is the key component-level building block for myriad RF power applications such as radar (defence, aerospace, and civilian—automotive), communications (defence, aerospace, and civilian—5G and beyond), signal jamming, and RF charging. These technologies are urgently required, especially by Defence and Aerospace agencies in India, as they are sensitive and controlled.

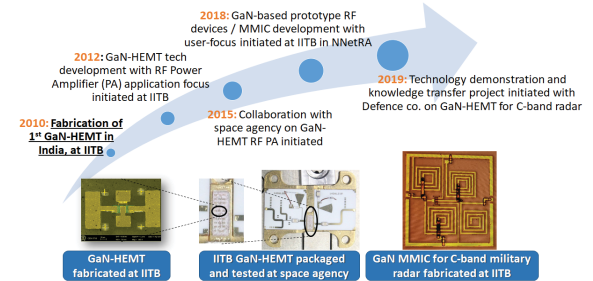
**Uniqueness of the Solution:** Gallium nitride (GaN) is a high speed and wide energy bandgap semiconductor material. A GaN-based High-Electron Mobility Transistor (HEMT) is a device drawing heavy attention and investment as the solution for RF Power applications. The team's benchmarking has revealed that the performance of the IIT Bombay GaN-HEMT technology is comparable to that of commercial vendors. The team offers licencing of GaN-HEMT fabrication

technology know-how, prototyping GaN-based devices and millimetre-wave monolithically integrated circuits (MMICs) for power amplifiers (PA), and design services for RF PA, with fabrication in the IIT Bombay fabrication lab or a commercial fab.

**Current Status of Technology:** The team has already been involved in technology demonstration and knowledge transfer projects with end-users in the Defence and Aerospace domain, namely a Defence Public Sector Enterprise and India's space agency.

**Societal Impact:** RF GaN-HEMT is a platform technology that can enhance the capability of space radars for remote sensing, space communications, automotive radar for safety, signal jamming for security purposes, including police/paramilitary operations, VVIP security, mega-event security and examination centres.

### RF GaN technology development by IITB team

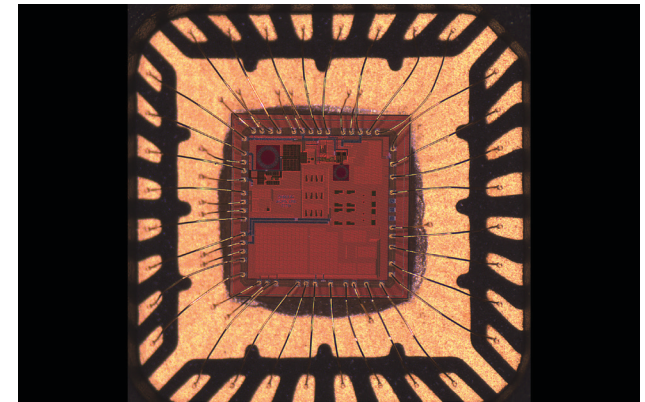


**Patent(s):** Filed

**Relevant Industries:** Defence, Security, Aerospace, Power.

**Faculty:** Prof. Dipankar Saha and Prof. Swaroop Ganguly, Electrical Engineering.

## Global Navigation Receiver Chip (Dhruva) Development



**Problem Statement:** Location services have become an essential part of everyone's life, particularly for navigation using mobile phones. The popular location service is the Global Positioning System (GPS) is owned by the United States of America. However, access to GPS is not always guaranteed. This prompted the Government of India to develop its indigenous satellite navigation system, NAVIC. However, none of the mobile manufacturers has incorporated NAVIC as a mainstream choice of a positioning system yet. Currently, there is no single unified solution that can receive all bands of NAVIC and various other Global Navigation Satellite Systems. This motivated researchers at IIT Bombay to develop NAVIC capable RF receiver called Dhruva.

**Uniqueness of the Solution:** Dhruva is the first indigenously designed compact reconfigurable navigation receiver chip to work for all navigation frequency bands of NavIC (L5 & S), GPS (L1 & L2),

Galileo, and BeiDou. The receiver is fully integrated with no external components, making it suitable for easy integration into SoCs for large-scale deployment in commercial applications. Dhruva consists of novel RF/Analog circuits to avoid external balun, matching network components. The on-chip PLL frequency synthesiser generates a wide range of desired reference RF frequencies. The IC is fabricated in 65 nm CMOS technology. The receiver occupies an active die area of only 1.96 mm<sup>2</sup>. With the achieved specifications, the IC can be readily used for commercial navigation applications (mobile phones, vehicle tracking, etc.) using NavIC (IRNSS), GPS, Galileo, and BeiDou.

**Current Status of Technology:** ISRO and MeitY have reviewed and measured IC results in detail during review meetings expressing complete satisfaction. Currently, the design team is working towards an advanced version of Dhruva with additional features and smaller size.

**Societal Impact:** It is suitable for easy integration into the System on a Chip for large-scale deployment in commercial applications such as vehicle tracking, marine vessel tracking, rail/road/water transportation monitoring, and other navigation applications.

**Patent(s):** Nil

**Relevant Industries:** Mobile Telecommunications, IT.

**Faculty:** Prof. Rajesh Harishchandra Zele, Electrical Engineering.

## Lead-Free Piezoelectric Ceramic for Replacement in Gas Lighters

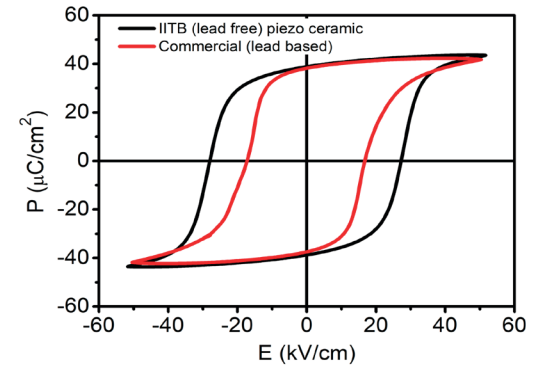
**Problem Statement:** Piezoelectric materials convert mechanical energy to electrical energy and vice versa. Commercially established lead-based piezoelectric materials like PZT are used in various applications, such as actuators, sensors, and transducer devices. Lead being toxic harms humans and the environment during manufacturing, use and disposal of household appliances, automobiles, and strategic and smart devices. Efforts to eliminate lead from piezoelectric ceramics have not yielded any new composition with useful piezo properties so that they may readily replace the well-established commercial compositions of PZT. Thus the problem of Pb pollution lingers on. The challenge is developing lead-free piezoelectric material for a direct and easy replacement of lead-based elements in the existing devices without requiring any other design changes and fabrication protocols.

**Uniqueness of the Solution:** The team has developed a new ceramic

composition with a few piezo coefficients superior to that of PZT used in the market for non-resonant (impact) applications as an alternative to lead-based appliances. The laboratory-developed lead-free ceramic has immense potential to be used in actuators, knock sensors, transducer devices, resistors, piezoceramic injectors, mist generators and ultrasonicators. In addition, it can cover all low to high-end, piezoelectricity-based applications.

**Current Status of Technology:** The laboratory developed lead-free ceramic is validated in the relevant field environment and is at the scale-up stage. A feasibility study of using the laboratory developed lead-free ceramic for gaslighter applications is being conducted in an Indian industrial hub.

**Societal Impact:** Lead-based piezoelectrics are widely used in various electronic devices. Replacing lead-based materials with lead-free materials in



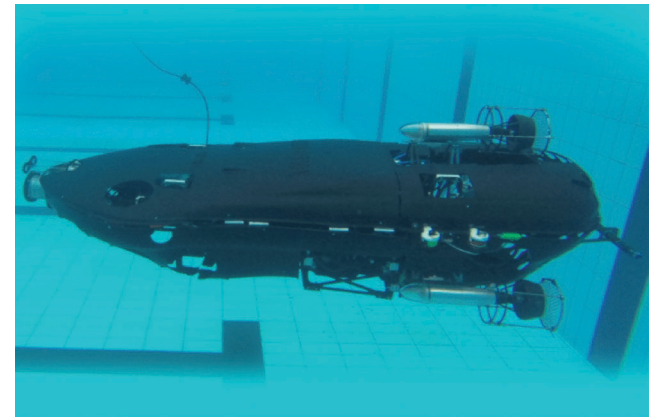
different electronic devices will lead to a safer environment.

**Patent(s):** Nil

**Relevant Industries:** Automobile Sensors, Actuators, Semiconductors and Consumer Appliances.

**Faculty:** Prof. Ajit Kulkarni and Prof. N. Venkataramani, Metallurgical Engineering and Materials Sciences.

## Matsya: Autonomous Underwater Vehicle



**Problem Statement:** Autonomous underwater vehicles (AUV) are required to achieve various tasks in inaccessible and sometimes hazardous locations where there is a compromise of human operator's safety. There are several applications of an AUV in critical domains of defence and robotics. IIT Bombay researchers address this requirement by designing and developing an in-house, low-cost AUV, aptly called Matsya (fish in Sanskrit). Their AUV can navigate obstacle-filled arenas, detect and avoid obstacles, and manipulate various objects placed underwater. The AUV can detect and shoot torpedoes at predefined targets (emulating defence applications) and locate underwater pingers using acoustic homing techniques (similar to finding an aircraft's black box). The AUV can also follow specific patterns on the arena floor (emulating oil pipes/underwater fibre optic cables).

**Uniqueness of the Solution:** The Matsya AUV is an indigenous modular solution

wholly designed and fabricated in India and has some excellent features. The components and complete software stack is developed in-house, making it cost-effective. The Matsya can be quickly deployed because it is highly portable and requires minimal support systems for launch and recovery. It requires no human intervention and has the capability of intelligent interpretations of sensor data, thereby resulting in autonomous operation. It has high endurance and a robust structure with a depth limit of ~50 m.

**Current Status of Technology:** The researchers have demonstrated the system prototype in an Operational Environment (Demonstrated in RoboSub 2019 at Transdec, San Diego, California, USA). It successfully performed tasks including shooting a torpedo, navigation, recognising patterns, and striking a buoy.

**Societal Impact:** The use of the Matsya AUV is free from risk to human operators because it can operate in hazardous

conditions and navigate to inaccessible locations. The product is indigenously designed and fabricated in India, and it supports the Atma Nirbhar Bharat ideology.

**Patent(s):** Nil

**Relevant Industries:** Defence, Robotics, Semiconductors, Manufacturing.

**Faculty:** Prof. Leena Vachhani, Systems and Control Engineering, Prof. Hemendra Arya, Aerospace Engineering.

## Measurement of Flame Temperatures using Ubiquitous Mobile Phone Camera

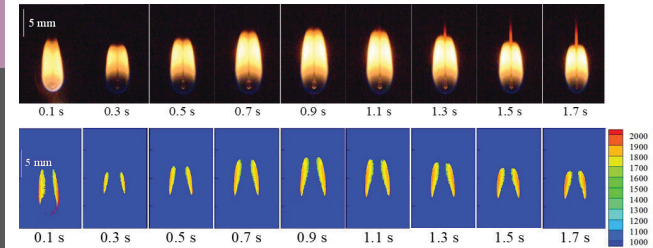
**Problem Statement:** Measurement of flame temperature is one of the cornerstones of combustion diagnostics. It directly impacts combustion efficiency and emission control, including mechanisms of soot formation and destruction. Commonly used non-intrusive methods of flame temperature measurements are expensive and may need significant technical expertise on the operator's side. They are also often inaccurate for sooty flames. The researchers have developed a solution to measure flame temperature using a mobile phone camera to overcome these shortcomings.

**Uniqueness of the Solution:** This technology is a low-cost, reasonably accurate solution for measuring the temperature of yellowish flames while combusting hydrocarbon fuels. Once the calibration is performed for a particular brand of camera-lens system, a cheap, cost-effective and robust unit is ready and capable of temperature

measurement. The technology is accessible to a wide population since smartphones are ubiquitous. The product being developed is an app that will work with compatible phone cameras. It can be made available to the end-user at a reasonable cost.

**Current Status of Technology:** The colour-ratio pyrometry (CRP) technique is validated in the lab using a commercially available CANON DSLR camera and a Samsung Note 10 camera. Predicted blackbody temperatures have been shown to be in good agreement with experimental observations. In addition, the flame temperatures for candles, McKenna flat flame, and droplet flames have been validated against thermocouple measurements using this technique.

**Societal Impact:** These environment-friendly sensors can be used in domestic and industrial applications where the monitoring of flame temperature is



essential. Additionally, these can also be used for measuring the temperature of solid/ opaque objects with temperatures over 1000 K. Contributing to a cleaner, more efficient combustion process helps build a sustainable environment for future generations.

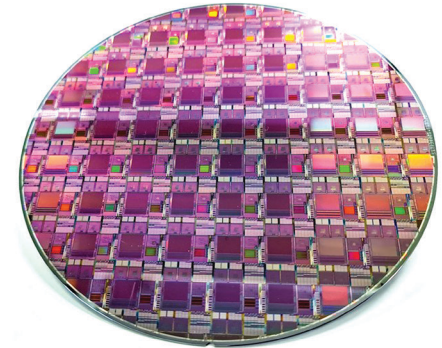
**Patent(s):** Nil

**Relevant Industries:** Thermal/Detection Industries, Thermo Sensors.

**Faculty:** Prof. Arindrajit Chowdhury and Prof. Neeraj Kumbhakarna, Mechanical Engineering; Prof. Anand S. Khanna, Metallurgical Engineering & Materials Science



## One-Time Programmable Memory Technology for 180nm CMOS



**Problem Statement:** In this connected world, electronic devices run our lives. The heart of electronics - Semiconductor chips are mass-produced, each ideally identical. Yet, manufacturing variations produce tiny offsets rendering chips useless and increasing the cost per chip. The tiny offset may be stored in a memory to correct the output, making each imperfect chip “perfect”! However, even the most advanced Fab in India, SCL Chandigarh, does not have this technology – thus suffering from significant yield loss, limiting efficiency, profitability, and customer satisfaction.

**Uniqueness of the Solution:** The IIT Bombay team has invented and demonstrated a memory cell and array-based on ultra-thin (2.5nm) insulator breakdown. The breakdown voltage is reduced to work at a standard supply of 3.3V compared to standard gate oxide technology requiring an excess of 6V. Thus, this technology avoids the penalty of large area high voltage generation

circuits. Further, the area of this memory cell is approximately three times smaller, which adds to the area advantage. The team fabricated OTP memory in a 180nm CMOS fab. This is the first-ever indigenous semiconductor memory technology adoption to manufacturing at the 180 nm node.

### **Current Status of Technology:**

The technology is implemented in a manufacturing line at 180nm CMOS Fab line (most advanced fab in India) to meet all technical specifications to result in successful technology adoption of the memory. Low rate production is demonstrated.

**Societal Impact:** Semiconductor chips are a key element of electronic imports that rival the oil import bill. Having an indigenous semiconductor product can reduce import expenditure and ensure self-reliance and security. This product can be used in space and defence applications, secure memory, and

hardware encryption for credit cards and EVMs. A major application is Near Field Communication chips for cashless transfers.

**Patent(s):** Filed

**Relevant Industries:** Robotics, Electronics, Sensors, Semiconductors.

**Faculty:** Prof. Udayan Ganguly, Electrical Engineering.

## Search and Reconnaissance using Spherical Robot



**Problem Statement:** Security agencies need assistance in their missions for search and reconnaissance. The researchers have developed a spherical robot that can help in such missions by transmitting real-time video feeds encompassing 360 degrees in unstructured and constrained environments. This robot also addresses the requirements of such a device that it should protect the internal electronics from impact and operate in stealth mode for security.

**Uniqueness of the Solution:** The spherical robot has a palm-sized ergonomic design that can be customised and upscaled to provide night-vision, audio, or any other application-specific sensing options. It has a 220-degree field of view and pan-360 degree vision system. The system includes a novel gearless two-pendulum-based actuation system to manoeuvre the robot. Ball-shaped outer body and gearless actuation facilitate withstanding impact.

The variants of the designed spherical robot can be fabricated based on the application: by varying size; providing wireless communication modules to collect video and audio feeds; payload carrying capability; and easy deployment option. Variant design with a low-cost solution is also possible. The researchers are working on lightweight video processing and multi-robot collaboration.

**Current Status of Technology:** The researchers have developed a functional prototype of the robot. The spherical bot prototype is a mobile rolling robot teleoperated with an Android app that provides a real-time pan 360-degree video feed. It has been tested at a simulated environment for room intervention operations in a testing facility with a security agency. Palm-size and Football-size variants of the spherical robot are developed as prototypes.

**Societal Impact:** The spherical robot can assist the security forces with search and

reconnaissance missions. The robot can be sent to infected areas to survey before actual contact to avoid casualties of our forces.

**Patent(s):** Filed

**Relevant Industries:** Robotics, Sensors, Electronics.

**Faculty:** Prof. Leena Vachhani, Systems & Control Engineering, Prof. Abhishek Gupta, Mechanical Engineering.

## U-Bent Optical Fibre Sensors



**Problem Statement:** Traditionally detection of bacteria and viruses has been done by culturing (and of late by PCR and associated techniques). ICP MS or ICP AES has been used to detect heavy metals. Mass Spectroscopy methods are used to detect organic molecules. However, these methods are time-consuming, require heavy capital investment, and require extensive expertise and interpretation of instrument outputs. These factors make deploying such techniques and instruments difficult at a vast scale.

**Uniqueness of the Solution:** The sensor developed by the team is easy to use, affordable, robust and reliable. The solution uses nanostructure-decorated U-bent optical fibres, which can be functionalised with suitable receptors which target specific analytes. The instrument consists of a light source (LED), a photodetector, electronics to process the light output, and a digital display. The system shows high

sensitivity. Capital investment and running costs for this sensor are low.

**Current Status of Technology:** The functionalisation of the sensor head for each of the analytes is at different levels. In some cases, it has been used with field samples, and in other cases, it has been used with simulated samples in the lab only. The prototype of the instrument, along with a cartridge design, has been tested in the lab.

**Societal Impact:** This solution can be used in water monitoring for drinking water, in monitoring intake and effluents of Effluent Treatment Plants (ETPs), Common and Combined Effluent Treatment Plants (CETP) and Sewage Treatment Plants (STP), food industry, and point of care devices in healthcare. This is one instrument that can be deployed at a large scale for a wide range of applications. The low capital and running costs make this a viable solution for many sensing applications.

**Patent(s):** Filed

**Relevant Industries:** Environment, Healthcare, Nanotechnology, IT.

**Faculty:** Prof. Soumyo Mukherji, Biosciences & Bioengineering.

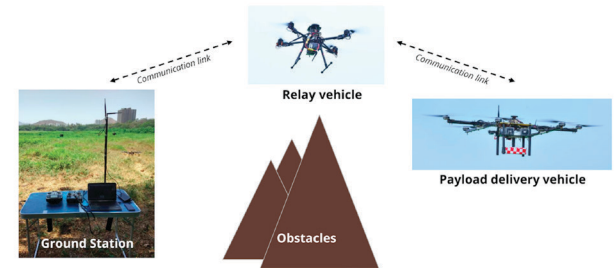
## Unmanned Aerial Systems Cooperative Mission for Search and Payload Delivery

**Problem Statement:** The team of researchers has been developing technologies to enable cooperative autonomous flight of unmanned aerial vehicles for multiple applications. For example, a team of robots or scout vehicles and payload vehicles coordinate for a given task for search or delivery operations. Researchers have developed a framework that enables the planning of missions requiring multiple vehicles. Their work addresses the need for quick area scanning using multiple vehicles for payload delivery at multiple locations autonomously.

**Uniqueness of the Solution:** The proposed solution uses multiple unmanned vehicles for higher efficiency in scanning large areas. Coordination between vehicles to increase the throughput of delivering payloads is a key feature. In addition, the computer vision pipeline in the framework makes the vehicles capable of onboard intelligence.

**Current Status of Technology:** The team has developed the prototype and completed testing in the laboratory and field-testing in relevant environments. 'Payload delivery beyond visual line-of-sight (BLOS)' with an intermediate agent acting as a communications relay between the ground station and the payload delivery vehicle is one sample mission that was executed in the IIT Bombay campus. Another sample mission, 'Search and Deploy', employs multiple scout vehicles designated to various areas to carry out the search and detect targets of interest and communicate the same to a payload delivery vehicle which then deploys the payload autonomously.

**Societal Impact:** The technology can be used to manage events spread over large areas and disaster management. This project has relevance in defence and internal security with specific applications for Humanitarian Aid and Disaster Relief (HADR) and Search and Rescue (SAR) missions.



**Patent(s):** Nil

**Relevant Industries:** Defence, Aerospace, Security, Automotives.

**Faculty:** Prof. Hemendra Arya, Aerospace Engineering.

**Smart Cities & Infrastructure (including smart mobility)**

# Decision Support System (DSS) for Urban Mobility



**Problem Statement:** India is a developing country with its road infrastructure and urban mobility developing rapidly. Therefore, it is necessary to evaluate the environmental impacts from road infrastructure and urban mobility throughout its life cycle. A tool for assessing the environmental impacts from road infrastructure and urban mobility and providing measures to reduce its impact is highly essential. There is some proprietary software like Decision Support System (DSS), but they are too costly and requires extensive time and effort for data collection; such a Decision Support System is essential for evaluating the environmental impacts. Addressing this gap, the researchers at IIT Bombay are proposing to develop a Decision Support System to assess the environmental impacts due to road infrastructure and urban transportation.

**Uniqueness of the Solution:** The DSS tool will require to feed standard details of road pavement such as the number

of lanes, width of each lane and length for which the user needs to evaluate the environmental impacts. Similarly, for urban mobility, the user will be required to feed data such as travel distance, fuel type, and the environmental impact will be estimated by the DSS tool. Since the tool would have all the key standards against which the impact assessment needs to be done, the evaluation can be done rapidly based on the input details.

**Current Status of Technology:** DSS tool development for road infrastructure is in the initial stage, and urban mobility is in the intermediate stage.

**Societal Impact:** The adverse environmental impacts due to road infrastructure and urban mobility are also related to society. These environmental impacts can cause adverse effects on human health and the whole society.

**Patent(s):** Nil

**Relevant Industries:** Cities, Towns, Urban Local Bodies, Municipalities.

**Faculty:** Prof Anil Kumar Dikshit, Environmental Science & Engineering.



# Integrated Municipal Solid Waste Management System (IMSWMS)



**Problem Statement:** Solid waste is produced from every household, commercial and industrial activity. However, in India, the collection, transportation and disposal of municipal solid waste (MSW) are unscientific and chaotic. Uncontrolled dumping of garbage on the outskirts of towns and cities has created overflowing landfills, which are not only impossible to reclaim because of the haphazard manner of dumping, but also have profound environmental implications in terms of groundwater pollution and contribution to global warming. The problem requires an efficient system for handling and management of solid wastes. Researchers at IIT Bombay have devised an integrated municipal solid waste management system to address this need.

**Uniqueness of the Solution:** An integrated waste management plan has been formulated to deal with fresh solid waste generated daily. According to this,

the trash needs to be segregated. The segregated waste is divided into dry, inert, and organic waste. The segregated dry waste is compacted and sent out for recycling. The segregated inert waste is repurposed as a filling material. The segregated organic waste is taken through a process of bio-stabilisation to realise it as a soil enhancer. The bio-stabilised organic waste can act as a very good bio-manure. Through effective implementation of these, municipal waste can be efficiently managed. However, a critical component is to ensure that waste segregation takes place during collection.

**Current Status of Technology:** The IMSWMS system has been successfully implemented by Mira Bhayandar Municipal Corporation (MBMC) in 2017 and by Naya Raipur Development Authority (NRDA) in 2018.

**Societal Impact:** Better solid waste collection and management, thereby reducing the problems due to solid waste.

**Patent(s):** Nil

**Relevant Industries:** Cities, Towns, Urban Local Bodies, Municipalities.

**Faculty:** Prof. Anil Kumar Dikshit, Environmental Science & Engineering.

# Mobile Water Treatment Plant (mWTP) for Emergency Situations

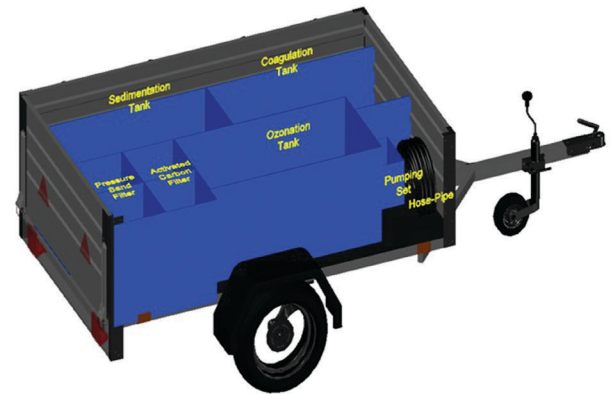
**Problem Statement:** India faces several natural disasters every year, mainly floods and storms. It is a daunting task for the government and relief organisations to provide clean water to the affected population in such situations. The disasters like floods and cyclonic storms severely affect the lives of the population, causing displacement of population, loss of life and property, a struggle for survival, food and water shortage. To provide relief to the affected population, we need specific solutions that can provide clean water on site. Addressing this need, researchers at IIT Bombay have designed a mobile water treatment plants system for emergency situations.

**Uniqueness of the Solution:** The proposed solution has a two-stage treatment approach. The solution contains a decision support system (DSS) along with a water quality testing system within it. Once the water source is fed, the water quality testing system assesses for water quality and shares

the results with the DSS. Based on the nature of water quality, the DSS will recommend/decide if the water should be treated in only one or two stages. In the first stage, the treatment options include coagulation, sedimentation, filtration and ozonation. Then, depending on the water quality and as per the DSS recommendations, the second stage of treatment is administered. In the second stage, the treatment options include membrane filtration and chlorination. Thus, depending on the water quality, one or two-stage treatment would be done for the water to make it potable.

**Current Status of Technology:** The conceptual design is ready, and further system design and fabrication is in progress.

**Societal Impact:** The system will help the disaster-affected population in reducing the chances of health problems in the aftermath of the disaster.



**Patent(s):** Nil

**Relevant Industries:** Metal Industry, Water and Power Industry, Mechanical Engineering, Pump & Filter Water Industry, Cities, Towns, Urban Local Bodies, Municipalities, Disaster Management Authorities, Army, Resorts.

**Faculty:** Prof. Anil Kumar Dikshit, Environmental Science & Engineering.

# SafeSan: Safe Sanitation System



**Problem Statement:** In India, more than 50% of the population lacks household toilets. Nearly 70% of the total sewage generated goes untreated. Under Swachh Bharat Abhiyaan, rural sanitisation (access to toilets) and urban wastewater management are the problems that need to be addressed. SafeSan is a decentralised sewage treatment unit that addresses this problem area.

**Uniqueness of the Solution:** SafeSan is an innovative decentralised sewage treatment unit. It provides the toilet with complete faecal treatment. Treated water can be reused for flushing or other non-potable uses such as irrigation or watering gardens. The system has lower cost, better disinfection capacity, low land requirement and is more efficient than conventional septic tanks. It also has a Longer Cleaning Frequency. The treatment unit has an organic removal efficiency of 85% and solid removal efficiency of 85%. In package form, it can be a prefabricated isolated toilet unit in

individual households or as a toilet block at a community level. It can also be used as a toilet solution for public convenience at public parks and public places such as bus stops, railway stations, or highways.

**Current Status of Technology:** The SafeSan system has gone through various stages of testing and has been successfully implemented. It stands at TRL-9. A unit was installed at a residential bungalow (not connected to sewerage systems) at Alibaug, near Mumbai, in 2015, and 50 stand-alone units were installed at Kaulkhed Gomase Village Akola District, Maharashtra, in 2020.

**Societal Impact:** SafeSan can provide safe sanitation/ toilets for everyone in residential and commercial establishments as a basic requirement. It is also in line with the objectives of Swachh Bharat Abhiyaan. It can provide clean and safe access to toilets in public places, rural areas, slums, and construction sites.

**Patent(s):** Nil

**Relevant Industries:** Urban Local Bodies, Rural Panchayats, Bus Stops, Railway Stations, Highways.

**Faculty:** Prof. Anil Kumar Dikshit, Environmental Science & Engineering.

## Smart Ultrasonic Water Meter with AMI



**Problem Statement:** Reliable and accurate water metering is crucial in the “water for everyone” mission. Metered water supply is necessary to achieve a fair water distribution across entire communities. Further, live monitoring and analysis of water supply & consumption patterns are necessary for efficient water management in smart villages, townships and cities. Among the various flow metering techniques, ultrasonic flow measurement stands out in terms of its accuracy, reliability, maintenance, and cost-effectiveness. However, few indigenously made ultrasonic domestic water meter is available. Addressing this challenge, researchers at IIT Bombay aimed to make a full-fledged ultrasonic water meter - high quality, reliable, rugged, and affordable ultrasonic meters for domestic potable water metering. The researchers have developed a state-of-the-art smart ultrasonic water meter with advanced metering infrastructure (AMI) technology. The product can be widely deployed by Water Supply Boards,

Municipalities, and Smart Cities for domestic water metering.

**Uniqueness of the Solution:** A fully functional, IOT compatible ultrasonic water meter with AMI is ready. The key features and capabilities are Automatic Meter Reading, Reliability, Accuracy, IOT ready, Data encryption, Low maintenance. The performance of the designed meter is found to match well with those of commercial (imported) meters. Product is believed to be a breakthrough, as it offers all the features of imported water meters, but at a fraction of their cost.

**Current Status of Technology:** The product is certified and fully ready for commercial production.

**Societal Impact:** The product plays a key role in drinking water metering. The benefits are consumer accountability, equitable distribution of drinking water, and reduction of non-revenue water (NRW). The product can be widely

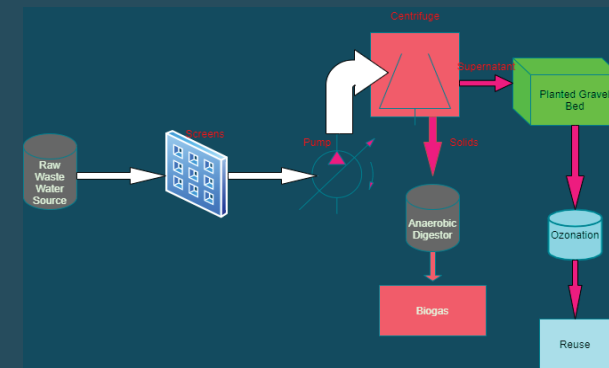
deployed by Water Supply Boards, Municipalities, and Smart Cities to save drinking water.

**Patent(s):** Nil

**Relevant Industries:** Water Supply Boards; Municipalities; Smart Cities

**Faculty:** Prof. P. S. V. Nataraj, Systems & Control Engineering.

## STP-on-Wheels: Decentralised Onsite Sewage Treatment Plant



**Problem Statement:** A tremendous amount of wastewater is generated from cities and travels very long distances to the conventional centralised wastewater treatment systems (CWTs), which results in various operational troubles. Sometimes, these CWTs cannot handle these large volumes of sewage. As a result, the waste is either partially treated or sometimes disposed of directly without any treatment into the water bodies, which in turn results in various adverse environmental impacts. These days, it is being felt, and in fact, several municipal corporations have already started requiring the proposed residential/ commercial/industrial projects to take care of their wastewater as well as solid and other wastes within their project areas. Researchers at IIT Bombay have proposed a decentralised onsite wastewater treatment plant to address this need.

**Uniqueness of the Solution:** Here on-spot safe and complete treatment of

wastewater generated at places of the collection grid such as slums, labour camps, the army in transit, fairs and exhibitions, holiday homes, industries, resorts etc., has been developed. Produced treated water can be reused for various non-potable uses, and hence the freshwater demand can be reduced. The proposed system has an option to treat wastewater in three ways after screening: One, through a centrifuge, to obtain biogas and treated water for reuse; Two, through a combination of aerobic, facultative and anaerobic treatment to treat water; and three, through a pre-settling tank and mechanical aeration unit, to treat water. Ozonation of the treated water is carried out in the last stage in all three options.

**Current Status of Technology:** A literature survey on various decentralised systems is in progress. The system is proposed; modifications will be done from time to time as the literature survey progresses.

**Societal Impact:** The negative environmental impacts due to partially or untreated wastewater discharge will be reduced, and the freshwater demand can be reduced.

**Patent(s):** Nil

**Relevant Industries:** Cities, Towns, Urban Local Bodies, Municipalities, Industries, Army, Resorts, Fairs and Exhibition Organisers.

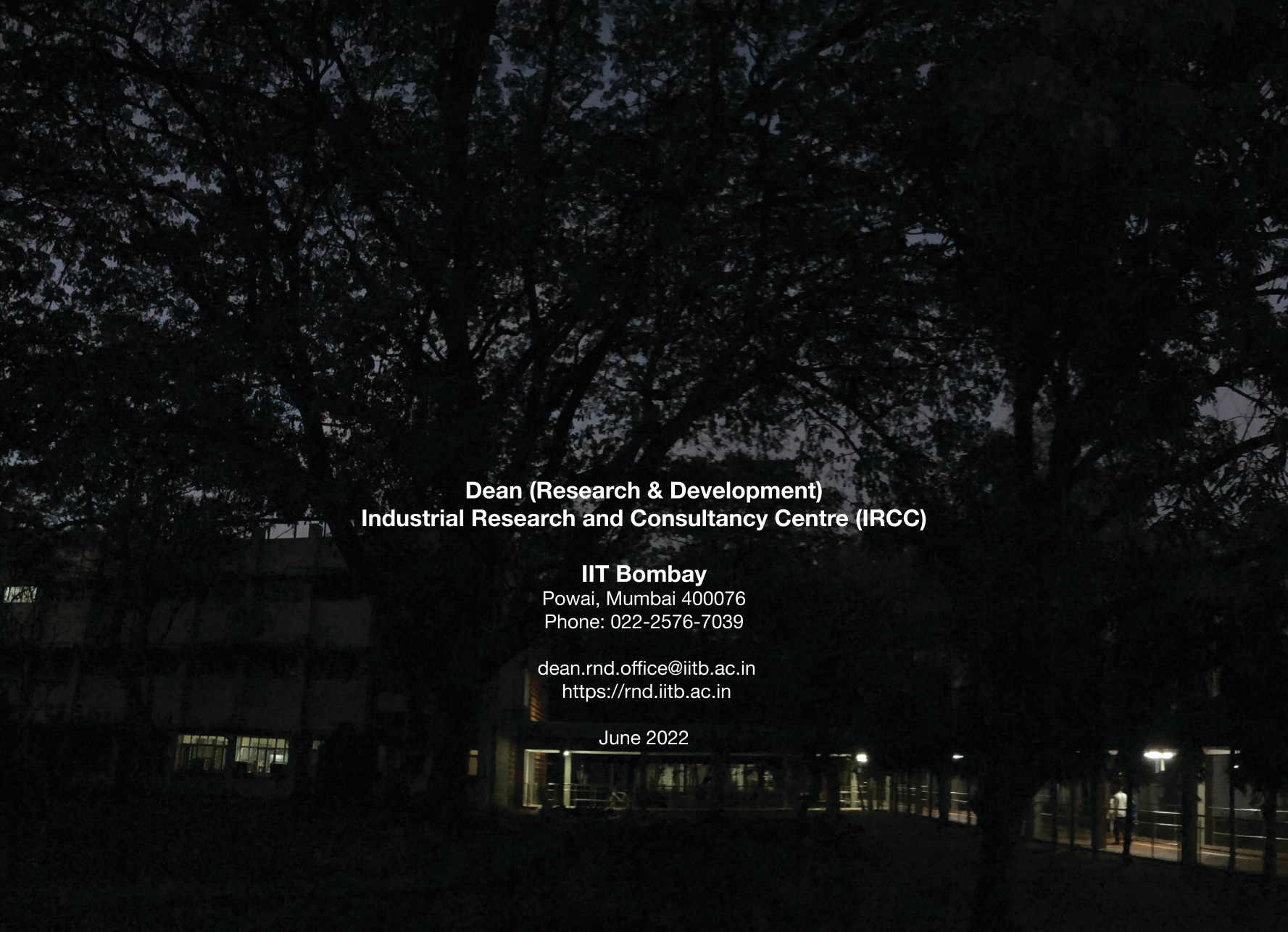
**Faculty:** Prof. Anil Kumar Dikshit, Environmental Science and Engineering.









A nighttime photograph of a building, likely at IIT Bombay, with large trees in the foreground. The building has some lights on, and the trees are silhouetted against the dark sky.

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