Joint PhD Programme of IIT Guwahati and IIT (BHU) Varanasi – December 2024

Sl. No.	01
Academic Division	Department of Chemistry
Project Code	JD_CH_SB-AI
Joint Supervisors	Dr. Shyam P. Biswas, Department of Chemistry, IITG: Dr. Arindam Indra, Department of Chemistry, IIT (BHU)
Title of the Project	Development of Self-Supported Metal-Organic Framework Electrodes for Electrochemical Hydrogen Evolution at Industrial Scale Current Density
Project Summary	The increasing global energy demand leads to the excessive use of fossil fuels, resulting in the release of a huge amount of greenhouse gases in the atmosphere. These gases have a significant impact on global warming and climate change. In this respect, hydrogen production by electrocatalytic water-splitting can fulfill the increasing energy demand. The Government of India has launched National Hydrogen Mission to rectify the dependency on fossil fuels as well as to take a leading role to fight against global warming. Although a significant development has been achieved in electrocatalytic hydrogen evolution using transition metal-based catalysts, the current density, attained by these catalysts, is not high enough for the industrial-scale application. Therefore, extensive research is required to fulfill the demand of the industry like the design of low cost and non-toxic materials, high current density (> 400 mA cm-2) at low overpotential (<100 mV) and durability of the catalysts. Looking at the above requirements, in this project, we will develop self-supported metal-organic framework (MOF) electrodes which can catalyze the cathodic hydrogen evolution reaction to reach more than 1 A cm-2 current density at a low overpotential. To attain this goal, we have chosen a self-supported approach, which ensures a strong contact between the solid-support and the catalyst and enhances the charge transfer process. In addition, the strong catalyst-support interaction increases the stability of the catalyst system. Further, the electronic and coordination structure of the MOFs will be fine-tuned to attain an optimized activity and stability of the catalyst system. Finally, a structure-activity relationship will be established based on the in situ and ex situ characterization techniques including X-ray absorption and Raman spectroscopic studies.

Sl. No.	02
Academic Division	Department of Electronics and Electrical Engineering
Project Code	JD_EE_RS-SB
Joint Supervisors	Dr. Ramesh Kumar Sonkar, Department of Electronics and Electrical Engineering, IITG; Dr. Somak Bhattacharyya, Department of Electronics Engineering, IIT (BHU)
Title of the Project	Studies on Photonic Metasurface Structures
Project Summary	Over the last few years, metasurface (MS)-based structures have generated profound interest among the research communities due to its compact nature as the artificial electromagnetic properties can be realized by exploiting the geometric dimensions. With the advent of time, metasurface structures have been proposed for several applications viz., absorbers, antennas, filters, polarization converters etc. However, the inherent high Q of the fundamental designs based on metasurfaces limits their applications. The use of super-cells as well as lumped elements have made the designs available for multiband as well as broadband applications. Another important feature of the MS that they have found their applications in enhancement of antenna parameters due to their multi-functional properties. Recently, antenna engineers focus on the development of MS antennas owing to low profile, wide bandwidth, and high gain

	features. Various research groups in India are involved in the development of metasurface structures for various applications in microwave domain; specifically covering C, X and Ku bands.
Sl. No.	03
Academic Division	Department of Mechanical Engineering
Project Code	JD_ME_UD-SK
Joint Supervisors	Dr. Uday Shankar Dixit, Mechanical Engineering, IITG; Dr. Santosh Kumar, Mechanical Engineering, IIT (BHU)
Title of the Project	Tackling Sustainability Issues in Additive Manufacturing
Project Summary	Additive manufacturing (AM) has gained enormous attention in the present digital era of sustainable manufacturing. It is popularly known as 3D printing and is one of the foundations of the fourth industrial revolution, i.e., Industry 4.0. This technology has promising applications in several fields, viz., medical, aerospace, construction, automobiles and electronics. Despite the unique advantages offered by AM, there is a hesitation in purchasing a 3 D printer and including it in the manufacturing route. Although it is adopted by some industries, its rate of adoption is not high as predicted in the past. One of the main reasons is the concern of sustainability. AM needs to be environmental friendly, cost-effective and socially relevant to compete with traditionally established manufacturing technologies. Some issues are material waste generated during the printing process, especially when supports or prototypes are discarded. There is a need of eco-friendly, biodegradable, or recyclable printing materials to reduce dependence on petroleum-based plastics. Additionally, the high energy consumption of some 3 D printers, particularly those using metal sintering or high-temperature processes, contributes to the carbon footprint, calling for more energy-efficient machines. Toxic emissions from certain materials also pose health and environmental risks, necessitating better filtration systems and safer alternatives. Furthermore, a comprehensive sustainability index must be developed to evaluate the environmental, economic, and social impact of 3D printing processes, helping industries to make informed choices for greener practices. Lastly, strategies for end-of-life management of printed products, such as recycling or repurposing, are essential to minimizing landfill waste and promoting a circular economy within the industry.
Sl. No.	04
Academic Division	Department of Biosciences and Bioengineering
Project Code	JD_BSBE_HS-PM
Joint Supervisors	Dr. Himanshu Singh, Biosciences and Bioengineering, IITG; Dr. Pandeeswar Makam, Chemistry, IIT (BHU)
Title of the Project	Designing Protein Probes for DNA Modifications
Project Summary	Living systems undergo a range of chemical changes on the four fundamental bases that are the foundation of life. In recent years, there have been notable advancements in the understanding of modified genomic bases and the enzymes involved in their processing. Understanding their role in human diseases is relevant, particularly in cancer and neurological disorders. In this backdrop, the aim is to understand the impact of novel nucleic acid modifications and their molecular recognition by nucleic acid-binding proteins from a structural and dynamic point of view. The amount of covalent DNA modifications like methylation and other oxidized cytosine forms (i.e; mC, hmC, fC, and caC) varies between tumors. However, because we don't have the right molecular probes to measure and detect them, we haven't been able to figure out how different combinations of these oxidised cytosine states (mC, hmC, fC, and caC) in CpG dyads affect the growth and spread of cancer. With our prior findings, we have been able to generate protein probes to quantitate hmC/mC asymmetric modifications. However, we still do not have a sensitive probe for quantifying hmC/hmC,

	fC/mC or fC/fC, and caC/mC or caC/caC. Therefore, we aim to develop unique and highly sensitive molecular protein-based probes for quantifying clinically relevant epigenetic covalent DNA modifications in gliomas and other aggressive cancers and moreover, dissecting the metabolic basis of cytosine oxidations and their associations with patient survival and response to treatment. To achieve the above goals, we plan to use a wide range of biophysical methods e.g. NMR-directed mutagenesis, protein dynamics-guided evolution, fluorescence-assisted cell sorting (FACS), chemically synthesized drugs, and technically advanced computational tools to find and choose the best protein binders. We will also figure out the structural and dynamic basis of the combinatorial CpG marks with oxidized-mCs that give the unique designer reader probe its ability to be selective. At the end of the project, we will establish a comprehensive picture of the chemical and cancer biology of the DNA modification processes in cancers and probe them with specific designed reader proteins. Later, similar principles could be applied to the design of proteins for RNA modifications, e.g., N^6-Methyladenosine (m6A).
Sl. No.	05
Academic Division	School of Energy Science and Engineering
Project Code	JD_EN_SV-AD
Joint Supervisors	Dr. Saket Verma, School of Energy Science and Engineering, IITG; Dr. Abhishek Suresh Dhoble, School of Biochemical Engineering, IIT (BHU)
Title of the Project	Sustainable Biogas Solutions: Optimizing Methane Production and Engine Performance
Project Summary	The escalating energy demands and environmental degradation resulting from the unchecked use of fossil fuels have necessitated a search for sustainable alternatives. In this landscape, biogas emerges as a compelling candidate, readily applicable in internal combustion (IC) engines for both vehicular and decentralized power generation. The primary components of raw biogas are methane (CH4), which determines its energy value, and carbon dioxide (CO2), which functions as a diluent. This dilution lowers the flame speed and heating value of biogas, adversely impacting engine performance. Traditionally, CO2 removal from biogas is viewed as a capital-intensive and environmentally unsustainable process. This research proposal aims to enhance the efficiency and viability of biogas-fueled energy systems by eliminating the need for extensive purification steps. Our approach has two main objectives: first, to develop specialized microbial consortia and modified anaerobic digestion bioprocesses to elevate CH4 content and reduce CO2 levels in biogas; and second, to create a hybrid energy system utilizing raw biogas, while assessing its performance and economic feasibility. Our previous studies validate this approach, demonstrating various biogas compositions, including BG93, BG84, and BG75, with respective CH4 concentrations of 93%, 84%, and 75% by volume, tested on a small CI engine in dual-fuel mode. The results indicate that biogas dual-fuel operation achieved 80-90% diesel substitution at lower engine loads. Notably, BG93 delivered performance comparable to diesel, with second-law efficiencies of 26.9% and 27.4%, respectively. The proposed research focuses on the following objectives: • Development of microbial consortia to enhance CH4 content and minimize CO2 levels in biogas. • Integration of bioprocess and IC engines to eliminate the biogas purification step. • Performance optimization of a raw biogas hybrid (battery) dual-fuel engine. • Techno-economic analysis of the proposed system for both mobile and stationary applications.