IITB-Monash Research Academy

An Indian-Australian research partnership

Indian Institute of Technology Bombay | MONASH University

Project Title:	**Enhanced performance of carbon supported catalysts for energy applications**	
Project Number	**IMURA1329**	
Monash Main Supervisor (Name, Email Id, Phone)	Prof Alan L Chaffee alan.chaffee@monash.edu	*Full name, Email*
Monash Co-supervisor(s) (Name, Email Id, Phone)		
Monash Head of Dept/Centre (Name,Email)	Prof Phil Andrews phil.andrews@monash.edu	*Full name, email*
Monash Department:	School of Chemistry, Faculty of Science	
Monash ADGR (Name,Email)	Prof Peter Betts	*Full name, email*
IITB Main Supervisor (Name, Email Id, Phone)	Prof Subramaniam Chandramouli csubbu@chem.iitb.ac.in	*Full name, Email*
IITB Co-supervisor(s) (Name, Email Id, Phone)		*Full name, Email*
IITB Head of Dept (Name, Email, Phone)	Prof Ruchi Anand ruchi@chem.iitb.ac.in	*Full name, email*
IITB Department:	Department of Chemistry	

Research Clusters:

Highlight which of the Academy's CLUSTERS this project will address?
*(Please nominate JUST **one.** For more information, see www.iitbmonash.org)*

1	*Material Science/Engineering (including Nano, Metallurgy)*
2	*Energy, Green Chem, Chemistry, Catalysis, Reaction Eng*
3	*Math, CFD, Modelling, Manufacturing*
4	*CSE, IT, Optimisation, Data, Sensors, Systems, Signal Processing, Control*
5	*Earth Sciences and Civil Engineering (Geo, Water, Climate)*
6	*Bio, Stem Cells, Bio Chem, Pharma, Food*
7	*Semi-Conductors, Optics, Photonics, Networks, Telecomm, Power Eng*
8	*HSS, Design, Management*

Research Themes:

Highlight which of the Academy's Theme(s) this project will address?
(Feel free to nominate more than one. For more information, see www.iitbmonash.org)

1	*Artificial Intelligence and Advanced Computational Modelling*
2	*Circular Economy*
3	*Clean Energy*
4	*Health Sciences*
5	*Smart Materials*
6	*Sustainable Societies*
7	*Infrastructure*

The research problem

Define the problem

Direct hydrogen combustion can provide an environmentally benign energy supply for many applications, since water is its only product. However, hydrogen is currently manufactured, principally, by the reforming of fossil fuels which leads to undesirable carbon dioxide emissions and hence an unsustainable approach. It is well known that hydrogen can be formed by electrolytic water splitting – but this is not yet economic at an industrial scale. There is an enormous incentive to develop improved catalysts, electrode (usually carbon-based) scaffolds and process configurations for electrolytic water splitting. Prospectively these improvements would enable the development of cheaper electrolysers and improved faradaic efficiencies. The development of cheaper carbon scaffolds, improved non platinum group metal (PGM) catalysts and shrewder methods for supplying the requisite energy to the active site(s) where water splitting and product gas evolution takes place can all assist this pursuit.

Recent advances at IITB have demonstrated that magneto-electro enhancement of water splitting over nickel and cobalt based nanoparticulates can be effective in significantly reducing overpotentials with consequential improvement in faradaic efficiency. Recent advances at Monash in the development of conductive carbon monolith possessing embedded metal nanoparticles have demonstrated that they are catalytic activity in liquid phase flow-through configurations that can be beneficial for process scaling. This project seeks to develop synergies across these advances with a view to the development of carbon-nanoparticle composites that facilitate water splitting with improved productivity.

Project aims

Define the aims of the project

This project aims to combine recent advances in the development and application of conductive carbon monolith materials with advancements occurring in the efficiency of water splitting via magneto-electrocatalytic enhancement. The ultimate objective goal is to facilitate demonstration of water splitting in a flow-through geometry that enhances productivity with substantially reduced overpotential. This will involve the preparation of novel carbon supported nano-particulate electrocatalysts and evaluation of their electrolytic performance with and without magneto-electric enhancement. This will be coupled with extensive characterisation of the materials by a range of surface science methodologies to build new knowledge of structure-property arrangements and direct further optimisation.

How skills/experience of the IITB and the Monash supervisor(s) support the proposed project

Highlight the purpose of the collaboration and/or the complementary skills/experience that you bring to the project. Do you have any joint or independent publications in the area of the proposed project?

A novel form of extruded carbon monolith with embedded metal nano particles was developed at Monash. It is prepared from cheap clean precursors (brown coal and waste carbonaceous material) and provides a contiguous parallel channelled construction that provides for a low pressure drop for both gas and liquid flow regimes. It also provides a large surface area for molecular species to adsorb and/or to react. Moreover the construction facilitates Joule (resistive) heating that can be applied to provide in-situ process heating. These features also make them attractive for applications as electrodes in electrochemistry applications. [See: Chem & Eng J, 471, 144699 (2023); J Anal Appl Pyrolysis, 190, 107117 (2025); J Mat Sci A 13 (41) 35368 (2025)]

IITB has recently demonstrated a synergistic magneto-electrocatalytic effect, so far based on the use of nanostructured hard carbon florets incorporating ferro-paramagnetic nanoparticles based on the non-PGM nickel and cobalt. For water splitting, very significant enhancements in the kinetics of the hydrogen evolution (HER) and oxygen evolution (OER) reactions have been demonstrated. This is at least partly facilitated by significant reductions in the overpotentials at the electrode that are induced by the magneto-electric effect. [See: ACS Sustainable Chem Eng 9, 7792 (2021); ACS Appl Mat Interfaces 15, 45855 (2023); ACS Sustainable Chem Eng 12, 8678 (2024)]

What is expected of the student when at IITB and when at Monash?

Highlight how the project will gain from the students stay at IITB and at Monash

At Monash, the student will focus on the preparation and characterisation of active carbon monoliths incorporating ferro-paramagnetic nanoparticles. This is likely to involve the use of synchrotron methods. Work at IITB will focus on evaluation of water splitting reactions and, in particular, achieving magneto-electrocatalytic enhancement of the reaction using novel carbon-metal catalyst formulations.

Expected outcomes

Highlight the expected outcomes of the project

The project is expected to bring new and novel mechanistic understanding to phenomenon of magneto-electrocatalytic stimulation of the water splitting reaction as well as determining how this might be effectively scaled-up into practical devices.

How will the project address the Goals of the above Themes?

Describe how the project will address the goals of one or more of the 6 Themes listed above.

The project targets the development of an environmentally benign and energy efficient solution for hydrogen production based on the use of improved catalyst and reactor design.

How well the IITB and the Monash supervisor(s) know each other

Provide details of previous collaborations (if any). For new collaborators, have you had a chance to meet each other in person or through VC or Skype?

Professors Chandramouli (IITB) and Chaffee (Monash) have previously collaborated through the co-supervision of a now-completed IITB student. This led to 2 joint publications in highly respected peer reviewed journals (J Mat Chem A and ACS Sustainable Chem Eng).
The now completed projected was supported and mentored by BASF.

Potential RPCs from IITB and Monash

Provide names of the potential research progress committee members (RPCs) and describe why they are most suited for the proposed project

From Monash: Assoc Prof Alexandr Siminov, who has extensive experience in electrocatalysis.
From IITB: tba

Capabilities and Degrees Required

List the ideal set of capabilities that a student should have for this project. Feel free to be as specific or as general as you like. These capabilities will be input into the online application form and students who opt for this project will be required to show that they can demonstrate these capabilities.

Masters degree in Chemistry or Chemical Engineering, preferably with some research experience in the development of carbon materials, catalysis and/or electrochemistry.

Necessary Courses

Name three tentative courses relevant to the project that the student should complete during his/her coursework at IITB (the student will require to secure 8 point in these courses)

Catalyst Development
Electrochemistry
Materials Chemistry

Potential Collaborators

Please visit the IITB website www.iitb.ac.in OR Monash Website www.monash.edu to highlight some potential collaborators that would be best suited for the area of research you are intending to float.

BASF or other catalyst development companies (India).
Energys (Melbourne)

K**eywords** relating to this project to make it easier for the students to apply.

Electrocatalysis, carbon monoliths, water splitting, magneto-electro stimulation