IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title:	**Catalytic Conversion of Algal Biomass into Tar Free Synthesis Gas by Reactive Flash Volatilisation**
Project Number	**IMURA0376**

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Research Academy 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. Advanced computational engineering, simulation and manufacture
2. Infrastructure Engineering
3. Clean Energy
4. Water
5. Nanotechnology
6. Biotechnology and Stem Cell Research

The research problem

Increasing CO2 concentration in the atmosphere and the globally depleting easily accessible crude oil has been a cause of concern for over a decade now. But clear solutions to obtain high quality and reliable

fuels and chemicals from biological feedstock have not yet been found. This research problem addresses one the biggest challenges, which is to convert third generation biomass (algae) into tar free synthesis gas using a reactive flash volatilisation process.

One part of the project will be focused on developing novel nanomaterial catalysts and process development of reactive flash volatilisation to produce synthesis gas with tunable CO:H2 ratio. Synthesis gas can then be converted to liquid fuels like methanol, ethanol, or dimethyl ether or chemicals like ethylene or propylene as a precursor for polyethylene and polypropylene. The tunability of CO:H2 in the reactive flash volatilisation will ensure that we will produce the correct ratio for the required downstream application.

The basic understanding of the reaction chemistry needs to be translated into reactor designs for practical implementation. The second part of the project, therefore, will focus on using model based tools to optimize reactor design. The models will be validated using the experimental studies.

Project aims

In this process we combine fast pyrolysis, gasification, tar-cleaning and the water-gas-shift reaction in one reactor. Dried algal biomass will be fed using a powder feeder. The air + steam feed reacts with the biomass on the catalyst bed and are converted to tar-free synthesis gas. Initially a selection of both micro and macro algae will be tested and best candidates for large scale harvesting and best conversion will be narrowed down. The aim is to develop suitable catalysts and reaction conditions to achieve a high yield and selectivity of CO and H2. The task for the student will be to develop new catalysts based on high surface area mesoporous materials; catalyst characterisation and testing in the reactor for high yield and selectivity for synthesis gas. By adjusting the carbon to oxygen ratio and carbon to steam ratio in the feed, it is possible that we can tune the CO:H2 ratio in the product from 1:1 to 1:3 depending upon the required downstream application. Later in the project full kinetics data will be generated which will validate the kinetic models developed in this project.

The process development research will be simultaneously complimented by developing an understanding about the reactor design and operation. Such understanding is especially important for processes occurring at high temperatures, such as flash volatilisation. We will develop detailed reaction kinetic models based on literature and validate those using the experimental studies. These models can be used to optimize reaction conditions and design. The computational fluid dynamics (CFD) based models have proved to be quite useful for modelling high temperature processes such as coal/biomass gasification. However, work on algal biomass has been somewhat limited. We will use prior knowledge of biomass and coal processing to model algal processing. We will identify the correct modelling approaches (such as Euler-Euler or Euler-Lagrange). The experimental results obtained concurrently as part of this project will be used to further fine-tune the model. Model simulations will be performed to determine the performance of selected reactor designs. The performance will be quantified in terms of production, syngas composition, as well as the temperature and pressure profiles within the reactor. These results will be compared with the experimental results. Model simulations will also be used to recommend experiments to be performed for improved understanding.

Expected outcomes

This project will deliver new understanding of the catalytic pathways of selective conversion of algal biomass into tar free tunable CO:H2 ratio synthesis gas. A kinetic model will be developed to understand the role of catalysts and reaction conditions on the conversion of biomass, the yield and selectivity of the synthesis gas. Finally the experimental data will validate the kinetic model. The project will also develop new CFD model for flash volatilization of algal biomass. The simulation results will compare different reactor designs and their performance. The results will, therefore, provide recommendations to help pilot or commercial scale implementation of the process.

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

Clean Energy – This project will develop new catalytic process for the industry for cleaner production of synthesis gas for further conversion to alternative liquid fuels or chemicals.

Nanotechnology – This project will develop novel catalysts based on nanomaterials such as porous metal

oxides, core-shell metal and metal oxide nanoparticles.

Advanced computational engineering, simulation and manufacture – The CFD model will make novel contributions in the area of computational modeling and simulation.

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.

The student will ideally have experience of research in one or more of the following disciplines - Chemical Engineering, Chemistry, Reaction Engineering, Catalysis and Materials Engineering, Process modelling, CFD modelling, Numerical methods.

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.

Additional costs and equipment

Describe below additional costs that would be needed to complete this project.
This would typically include project-related costs (such as consumables).
Computers, desks, conference travel, student travel to Australia, etc should not be included here. They are already provided for.
IF AMOUNT BEING SOUGHT IS IN EXCESS OF INR 3 lakhs OR $6000, PLEASE COMPLETE FOLLOWING SECTION AS WELL

Equipment required for this project will be provided from the existing lab infrastructure available at IITB and Monash University. The following things are requested in this project –

- Project related consumables such as catalysts precursors and analysis of the projects in HPLC and GC will be required.
- Modelling and simulation software may be required

Please provide a few key words relating to this project to make it easier for the students to apply.