IITB-Monash Research Academy

An Indian-Australian research partnership

Indian Institute of Technology Bombay | MONASH University

Project Title:	**Solar modules – Life after Death**	
Project Number	**IMURA1063**	
Monash Main Supervisor (Name, Email Id, Phone)	Prof. Neil Cameron, neil.cameron@monash.edu	*Full name, Email*
Monash Co-supervisor(s) (Name, Email Id, Phone)		
Monash Head of Dept/Centre (Name,Email)	Prof. Neil Cameron, neil.cameron@monash.edu	*Full name, email*
Monash Department:	Materials Science and Engineering	
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IITB Department:	Metallurgical Engineering And Materials Science	

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

Solar photovoltaic module installations have been increasing exponentially globally, and rightly so. The modules typically have a lifespan of 20-25 years. This means the quantity of discarded PV modules is also expected to increase rapidly in the coming decade. The modules contain various materials such as Aluminum coatings, Silver, Electronic grade Silicon, Solar glass, etc. Developing technologies to recycle and recover these materials is of prime importance.

Modules designed to be hermetically sealed for more than 20 years. Even at 'End-of-life,' the module is still likely to be intact, only with localized defects or producing less power. Delamination of such a well-sealed composite structure is not simple. It is even more challenging to delaminate if recovery of intact components is desired.

The project will involve the delamination of modules by pyrolysis of the encapsulant. The solar cells collected from these are likely to be cracked. They contain valuable Ag and Al. Extraction of these to generate byproducts in a commercially viable manner and to repurpose the extracted materials to fabricate new modules is a key challenge.

Project aims

Define the aims of the project

The process is envisaged to be carried out in two stages – first, on a single-cell mini-module fabricated in-house, and then on small commercial modules

- Delamination to separate Aluminum frame, intact glass, and possibly intact solar cells.
- Leaching and electrowinning of Ag and Al from the Solar cells
- Synthesize byproducts of Ag and Al
- Explore the use of the recovered Si in steel refining
- Fabricate new modules using intact solar glass. Potentially reuse the Aluminum frame too.

Alternate encapsulant materials will be evaluated, which can help make the module easier to recycle while providing lifetime equivalent or better than EVA.

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 IITB, the student is expected to gain expertise in fabricating PV modules. Mini modules will be manufactured using the facilities available at IITB. The next stage would be to experiment with techniques to delaminate the modules using a combination of thermal/ Mechanical and Chemical methods.

Intact solar glass - which is tempered and textured, is expected to be one of the main components recovered from the recycled modules. Assembly of new modules using the components recovered from the delaminated modules will be attempted.

At Monash University, the student can study the polymer degradation aspects and the byproducts produced and investigate ways to minimize the generation of potentially hazardous gases and effluents during recovery. Alternative polymer encapsulants will also be developed and studied with in-house generated PV modules.

Expected outcomes

Highlight the expected outcomes of the project

- Demonstration of module delamination by various methods – Chemical/Thermal/Physical
- Recovery of module components – Glass, Solar cell (Intact or broken)
- Reuse – If the intact glass is recovered, attempt the re-manufacture of a fresh panel
- Recovery of Al, Ag from the Solar cell by chemical leaching
- Explore the use of the recovered Si in steel refining

Alternate encapsulant materials will be evaluated to help make the module easier to recycle while providing a lifetime equivalent or better than EVA.

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 aims to develop methodologies for recycling end-of-life Photovoltaic modules. This is in good consonance with the themes of 'Clean Energy,' 'Sustainable society,' and 'Circular Economy.' As the adoption of PV technology is poised to increase exponentially over the following decades, so will the amount of waste discarded modules generate. Unless a solution to responsibly manage this problem is found, the large-scale adoption of this Clean Energy source will result in burgeoning landfills.

The materials recovered from the recycled modules can potentially be reused for fabricating new modules or for other applications.

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 IIT Bombay:

1. Prof. Anil Kottantharayil (Electrical Engineering): He leads the Si PV group the National Centre for Photovoltaics Research and Education (NCPRE)
2. Prof. Narendra Shiradkar (Electrical Engineering): He leads the PV module reliability group at NCPRE

Both Prof. Anil and Prof. Narendra also have close interactions with Module manufacturers and Large scale PV power organizations.

3. Prof. Arup Bhattacharya (Metallurgical Engineering and Materials Science): He has expertise in polymer processing, which will be beneficial for the project.

From Monash University:

1. Prof. Jacek Jasieniak (Materials Science and Engineering): He is an expert in energy harvesting and storage materials, and former Director of Monash Energy Institute.
2. Prof. George Simon (Materials Science and Engineering): He has tremendous expertise in polymer materials development and materials durability.

3. Dr Matthieu Gresil (Materials Science and Engineering): He is an expert in polymer materials and sustainability.

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.

Experience with chemical synthesis,
Materials characterization
M.Sc. in Chemistry,
M.Tech in Polymers,
M.Tech in Chemical Engineering,
M.Tech in Materials Science and related disciplines
Candidates from other disciplines are also welcome to apply if they have expertise relevant to the project.

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)

The courses for the student will be decided mutually based on the student's background. Some of the potential courses at IITB could be the following:

Department	Course code	Name
Chemical Engineering	CL 624	Polymer Processing
Chemistry	CH 442	Molecular Spectroscopy
Chemistry	CH 602	Characterization of Polymers
Energy	EN 640	Solar Photovoltaic, Fundamentals, Technologies and Applications
Met. Eng & Mat. Sci.	MM 452	Plant Engineering

Met. Eng & Mat. Sci.	MM 453	Engineering polymers and composites
Met. Eng & Mat. Sci.	MM 644	Mathematical Methods of Materials Engineering.

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.

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From Industry:
ReNew Power Pvt. Ltd, Other Solar power industries, and module manufacturers.

Select up to **(4)** keywords from the Academy's approved keyword list **(available at http://www.iitbmonash.org/becoming-a-research-supervisor/)** relating to this project to make it easier for the students to apply.

Energy, Energy Storage, Energy Materials	2
Waste to Wealth	3
Green Chemistry and Renewable Energy	18
Materials Chemistry/Science	20
Miscellaneous/Uncategorized	24