IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title:	**Peptide-Polymer Conjugates for Ion-Binding**	
Project Number	**IMURA1280**	
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IITB Department:	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

Recovering critical minerals from waste streams remains a pressing and complex challenge in the transition to a sustainable and secure supply of key industrial materials. As global demand for technologies such as electric vehicles, wind turbines, and electronics surges, so too does the need for critical minerals like lithium, cobalt, rare earth elements (REEs), tellurium, and antimony. These materials are essential for energy storage, permanent magnets, and advanced electronics—but their extraction from primary sources is often environmentally damaging, geopolitically fraught, and economically volatile. Meanwhile, vast amounts of these same minerals are discarded in spent batteries, electronic waste, mining tailings, coal ash, and smelting byproducts, creating both an environmental hazard and a missed opportunity.

Despite advances in hydrometallurgy, bioleaching, ionic liquid extraction, and membrane-based separation technologies, recovering critical minerals from waste remains technically and economically challenging. Waste streams are often complex and heterogeneous, requiring selective, energy-efficient, and scalable recovery processes that remain elusive. Biological and electrochemical methods show promise but still face hurdles in terms of yield consistency, process integration, and regulatory approval. Furthermore, there is a lack of infrastructure and standardisation for collecting, pre-sorting, and processing these secondary resources. Unlocking the potential of waste as a viable source of critical minerals will require interdisciplinary innovation, policy support, and investment in circular economy infrastructure—making it a grand challenge for sustainable materials engineering.

Project aims

Define the aims of the project

The project will consist of 3 phases:

1. The design and synthesis of peptides for selective binding of critical minerals of interest
2. The coupling of peptides to polymer support materials to enable easy recovery of the extracted minerals from liquid media
3. Testing of the materials in simulated and real waste streams.

The aims of the project can therefore be defined as

1. Synthesis of peptide macrocycles capable of high affinity binding of selected metal ions
2. Production of porous polymers as support materials
3. Chemical attachment of peptides to polymer supports
4. Selective uptake of metal ions from aqueous solution

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?

Prof Neil Cameron has enormous experience in the development of porous polymer materials which are used for applications including the immobilisation of catalysts (metals, organocatalysts, biocatalysts) and the selective extraction of pollutants. He is also developing a new research program in the valorisation of different waste streams. Selected publications of relevance to this project:

Prof Nandita Madhavan has expertise in engineering small organic molecules, macrocycles and peptides for selective-binding of metal ions and anions. These materials have been applied as synthetic ion channels in lipid membranes and as conjugates with polymers for ion encapsulation.

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 will develop efficient synthetic methods to access peptide and macrocyclic scaffolds with a specific affinity for ions of interest. The student will test the ion-selectivity of the peptides in solution using suitable spectroscopy techniques. The best peptides will be further modified to enable conjugation with porous polymer substrates.

At Monash University, the student can study the loading of functional peptides onto porous polymer substrates and their ability to recover metals of interest from different types of aqueous media (simulated and real). Peptide loading efficiency will be determined together with metal uptake and release studies. Porous polymers can be characterised by SEM, mercury porosimetry, BET analysis and Xray micro-CT.

Expected outcomes

Highlight the expected outcomes of the project

- New macrocycles or acyclic peptides for metal ion binding
- Functionalised porous polymers for metal ion recovery from solution
- A method for harvesting critical minerals from aqueous waste streams
- High impact publications and/or commercialisable technology
- High quality PhD thesis
- A PhD student with advanced training in an area of relevance to industry

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 concerns developing new materials and methods for the recovery of critical minerals from waste streams, and thus it addresses directly the themes **Clean Energy**, **Circular Economy** and **Smart Materials**. Certain minerals are vital for energy applications, for example lithium, nickel and cobalt are used in batteries. The project will harvest these minerals and others from waste streams, representing a circular economy approach to critical minerals. Furthermore, the peptide-functionalised materials represent next generation smart materials for critical mineral recovery.

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?

This is a new collaboration between Profs Cameron and Madhavan. We know each other quite well from previous visits to each other's institutions and from acting as RPC members for each other's students, however we have not yet worked together. Both Profs Cameron and Madhavan have considerable experience as supervisors of IITB-Monash Academy PhD students.

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 IITB:

1. Prof Arnab Datta (Chemistry) – expertise in ion-binding for clean energy applications
2. Prof. Srinivasan Ramakrishnan (Chemistry) – expertise in materials for battery applications
3. Prof Swatantra Pratap Singh (Environmental Science and Engineering) – expertise in polymer membranes for water purification

From Monash University:

4. Prof Tanja Junkers (Chemistry) – she is an expert in polymer science
5. Dr Leonie van't Hag (Chemical and Biological Engineering) – an expert in sustainable materials and bioprocessing
6. Prof Jacek Jasieniak (Materials Science and Engineering) – an expert in renewable energy

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 of chemical synthesis; knowledge of materials science and characterization
M.Sc in Chemistry
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:
CH 584 – Biophysical Chemistry
CH 521 – Interpretative Molecular Spectroscopy
CH 839 – Physical Organic Chemistry and Stereochemistry
CH 815 – Inorganic Electrochemistry
CH 552 – Interfacial Phenomena

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.

From IITB:

1. Prof. Srinivasan Ramakrishnan (Chemistry) – expertise in materials for battery applications
2. Prof Swatantra Pratap Singh (Environmental Science and Engineering) – expertise in polymer membranes for water purification

From Monash:
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 developing

polymer materials and durability.
3. A/Prof Matthieu Gresil (Materials Science and Engineering): He is an expert in polymer materials and sustainability

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

Critical minerals
Sustainable materials
Polymer chemistry
Organic chemistry
Peptides
Circular economy
Energy and energy storage