IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title:	**Development of porous polymers as scaffolds for sodium ion-and potassium-ion supercapacitors**
Project Number	**IMURA0912** *(will be inserted by The Academy)*

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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	*Advanced computational engineering, simulation and manufacture*
2	*Infrastructure Engineering*
3	***Clean Energy***
4	*Water*
5	***Nanotechnology***
6	*Biotechnology and Stem Cell Research*
7	*Humanities and social sciences*
8	Design

The research problem

The demand for efficient and clean methods for storing electrical energy has been rapidly escalating, particularly with the perceived paradigm shift to cleaner and renewable energy sources. Supercapacitors store electrical energy in the form of double layer at the electrode-electrolyte interface. The supercapacitors exhibit the ability to assimilate intermittent energy sources and therefore form the key to interfacing with renewable energy harvesters such as solar, wind and tidal. However, the major limitation of supercapacitors is their low energy density; a parameter that describes the amount of energy that can be stored. Further, their self-discharging ability results in poor energy-storage efficiency. These challenges can be overcome by developing hybrid ion-capacitors that synergistically combines the intercalation-type electrode with electrical double layer forming electrode into a single device. Consequently, such hybrid Na+/K+ ion-capacitors are expected to exhibit high power density (similar to supercapacitors) and high energy density (such as

Li+/Na+ batteries), along with long cycle life.
Major impediments to the development of such hybrid Na+/K+ ion-capacitors are (a) lack of appropriate layer spacing of carbon-based nanomaterials for reversible intercalation of the alkali-metal ions, and (b) poor ionic conductivity of solid-state electrolytes.
Intercalation often involves covalent bond formation between the carbon and alkali-metal atom, which adversely affecting the reversibility of the reaction and thereby the cycling-life of the energy storage system. The strength of this covalent bond decreases as per Li^{+}>Na^{+}>K^{+}. Accordingly K+ ion has the least intercalation stability and hence offers the highest reversibility of such systems. However, the large hydrodynamic size of K+ demands expanded interlayer spacing that is usually difficult to achieve with strongly van-dew Waals solids containing delocalized, pi-electron rich systems such as graphene and carbon nanotubes.
Ionic conductivity is directly related to the mobility of the ions in liquid state. However, high ionic conductivity in solid-state electrolytes has been elusive. Solid state electrolytes often involve combination of ionic-components stabilized by polymeric matrices. The low ionic conductivity of such electrolytes results in significantly reducing the energy and power density of such systems. Therefore, it is important to realise high ionic conductivity without compromising on the mechanical robustness.

Project aims

The project would focus on:

1. Design and development of porous polymeric scaffolds that facilitate the transport of potassium and sodium ions.
2. Design and development of carbon nanostructures with turbostatic graphitic arrangement and extended interplanar spacing for reversible intercalation of sodium and potassium ions.
3. Fabrication of all-solid-state hybrid ion-capacitors with high energy density and power density, with demonstrable mechanical flexibility.

Expected outcomes

Highlight the expected outcomes of the project including likelihood of patents

- A highly trained PhD student with broad expertise in materials science and engineering, and clean energy
- High impact publications
- Commercially exploitable IP

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.

Clean energy: the work will create new supercapacitor devices which are capable of efficient storage of clean energy generated from non-fossil fuel sources.

Nanotechnology: the active component of the devices is nanostructured carbon florets (NCF) developed by Subramanian.

Capabilities and Degrees Required

List the ideal set of capabilities that a student should have for this project. 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 should be excited about the prospect of working on an interdisciplinary project to develop new materials and devices that can store clean energy. He or she should have a background in a physical science or engineering subject, and should be willing to gain new knowledge in polymer science, nanomaterials and functional materials.
Expertise in electrochemical techniques and/or working with glove box is preferred.

Necessary Courses

List three tentative core 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)

Electrochemistry of solutions and interfaces
Electrochemical and Materials Perspective in Energy Storage

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.

N/A

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.

Novel Functional Materials; Energy, Energy Storage, Energy Materials; Nanotechnology, nanoscience; Novel Batteries and Fuel Cells