IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title: **High Energy Density Lithium - Ionic Liquids Batteries**

Project Number **IMURA0379**

Reliance Industries Limited

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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

Define the problem

Based on recent discoveries from our group[1-5], this project will develop advanced high energy density lithium ion batteries through a combined approach to create advanced high-energy cathode and anode materials and architectures, the application and development of which will be enabled by new ionic liquid electrolytes with enhanced electrochemical and thermal stability. This comprehensive approach to the combined development and improvement of all of the active components of the battery will draw on the

leading expertise of the participant teams, all world leaders in their area of specialty.

Current Li-ion batteries are limited in their application due to capacity, temperature and stability issues. Achieving the stated goals of the project would allow the demonstration of viable Hybrid Electric Vehicle and Electric Vehicle batteries capable of satisfactory range performance in many city environments.

Increasing the energy density and voltage Li-ion cells places extreme demands on all components of the device, particularly when required to operate over a wide range of temperatures and loads. Thus the key issue faced by this approach is the delivery of devices with improved stability and cycling lifetimes. Substantial supporting funding would allow the proposed approach to proceed rapidly towards its goals, utilizing the expertise of disparate, leading research groups, to work together with access to resources and capabilities that will not otherwise occur.

(1) Yoon, H.; Lane, G. H.; Shekibi, Y.; Howlett, P. C.; Forsyth, M.; Best, A. S.; MacFarlane, D. R.: Lithium electrochemistry and cycling behaviour of ionic liquids using cyano based anions. *Energy & Environmental Science* **2013**, *6*, 979-986.

(2) Bayley, P. M.; Best, A. S.; MacFarlane, D. R.; Forsyth, M.: Transport Properties and Phase Behaviour in Binary and Ternary Ionic Liquid Electrolyte Systems of Interest in Lithium Batteries. *Chemphyschem* **2011**, *12*, 823-827.

(3) Bayley, P. M.; Best, A. S.; MacFarlane, D. R.; Forsyth, M.: The effect of coordinating and non-coordinating additives on the transport properties in ionic liquid electrolytes for lithium batteries. *PCCP* **2011**, *13*, 4632-4640.

(4) Armel, V.; Velayutham, D.; Sun, J. Z.; Howlett, P. C.; Forsyth, M.; MacFarlane, D. R.; Pringle, J. M.: Ionic liquids and organic ionic plastic crystals utilizing small phosphonium cations. *J. Mater. Chem.* **2011**, *21*, 7640-7650.

(5) Janikowski, J.; Forsyth, C.; MacFarlane, D. R.; Pringle, J. M.: Novel ionic liquids and plastic crystals utilizing the cyanate anion. *J. Mater. Chem.* **2011**, *21*, 19219-19225.

Project aims

Application of Ionic liquid as Li ion battery electrolytes still a challenge, and the specific factors that need to be looked at more carefully like the viscosity, compatibility with electrode chemistries, and solid-electrolyte interphase (SEI) forming capability of ionic liquids. Use of all functionalities of ionic liquids as lithium-ion battery electrolyte, one could study in details like conductivity, thermal and electrochemical stability as well as electrode-electrolyte interface. Interfacial properties are more crucial while high voltage cathodes like $LiMnNiO_2$ and Li_2FeSiO_4 are used where maximum operating cell voltage is govern by the electrochemical stability of the electrode–electrolyte interface.

In this project, one of the high voltage electrodes (mainly $LiMnNiO_2$ and Li_2FeSiO_4) will be prepared and their stability, cyclic performance and interfacial properties will be evaluated.

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Expected outcomes

- *Suitable combination of ionic liquid as electrode for high voltage cathode*
- *Cost effective high voltage cathode preparation method*
- *Extensive electrochemical study on high voltage cathode with ionic liquids*
- *Fundamental understanding of few important parameters for better electrode-electrolyte interface design*
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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.

Capabilities and Degrees Required

- *Chemistry as major with sound knowledge in inorganic material synthesis, electrochemistry and solid-state chemistry*

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.