Advanced cell chemistry for aluminium-based rechargeable batteries

Highlights

- Improved battery performance using materials that combine economic and environmental sustainability with technically useful energy and power density to compete with existing technologies
- Improved battery safety via use of non-flammable electrolytes (ionic liquids and gels) and Al electrodes
- Development of batteries with recoverable metal components, compliant with environmental legislative requirements

Overview

Batteries are of increasing importance in zero emission vehicles, mobile computing and communication, energy storage from (intermittent) renewable sources, back-up for grid failure, and operation in “off-grid” environments. Notwithstanding recent technical and performance advances, most obviously in lithium batteries, several factors motivate the search for new battery cell chemistries. These include longer life time, longer cycle life, increased energy and power densities, safety, environmentally benign active materials and electrolytes, cost, and sustainable strategic availability of active materials (notably metals).

This project centres on aluminium-based batteries, which promise high energy density. Aluminium is the most abundant metal in the earth’s crust and occurs widely; accordingly, it is substantially cheaper than metals presently used in battery systems, whether as the insertion ion (Li) or within the active material (e.g. Ni, Mn, Co). It is intrinsically safe and compatible with environmentally benign electrolytes.

These advantages are accompanied by several materials challenges, notably: controlled nucleation and growth during deposition of coherent dense aluminium films of defined morphology and their coulombically efficient dissolution during charge/discharge cycling; minimisation of mechanical stress (leading to delamination); and aluminium corrosion in aqueous media. Variation of aluminium speciation (complexation reactions), use of electrolyte additives and selection of electrochemical control function will be used to deduce deposition/dissolution mechanism; physical measurements will characterise the film structure. Corrosion issues will be addressed via trace
alloying components (e.g. Mg and Sn) and novel media such as ionic liquids and gel electrolytes containing inhibitors. These electrolytes are consistent with graphite or conducting polymer (notably poly(3,4-ethylenedioxythiophene), PEDOT), cathode materials.

In summary, the project will develop and characterise new cell chemistries using Deep Eutectic Solvent (DES) and gel electrolyte media in combination with abundant, inexpensive and safe active metal components (aluminium alloys) and lightweight polymer charge storage membranes. The experimental programme will utilise state-of-the-art facilities in the University of Leicester Materials Centre and at (inter)national large scale facilities to characterise structural properties of individual anode and cathode materials and transport dynamics within the electrolytes. The fundamental studies will be complemented by fabrication and characterisation of prototype coin cell batteries and multi-channel charge/discharge cycle testing.

Methodology

Fundamental studies of electrodes and electrolytes will involve electrochemical and non-electrochemical techniques. Selected electrochemical control functions (potentiostatic, potentiodynamic, galvanostatic) will impose kinetic or transport control over aluminium deposition/dissolution and the temporal responses used to determine nucleation and growth mechanisms and kinetic parameters. Acoustic wave measurements, in nanogravimetric and admittance modes, will be used to determine deposition efficiency and to detect and quantify internal stress.

Optical measurements will be used to explore locally deviant solution chemistry at high metal dissolution rates; where detected, these will inform synchrotron X-ray (EXAFS) determination of metal/ligand speciation. Microscopy methods will be used to explore electrode external morphology. Internal film composition will be determined in real time during deposition/dissolution using event mode neutron reflectivity (Rutherford Laboratory ISIS neutron facility). Additional access to centres of excellence will exploit existing collaborations with the Warwick Manufacturing Group, The Welding Institute and the Midlands Energy Research Accelerator.

Further Reading


Funding

This research project is one of a number of projects in the Department. It is in competition for funding with one or more of these projects. Usually the project which receives the best applicant will be awarded the funding.

Home/EU Applicants

This project is eligible for a fully funded College of Science and Engineering studentship which includes:
• A full UK/EU fee waiver for 3.5 years
• An annual tax free stipend of £14,777 (2018/19)
• Research Training Support Grant (RTSG)

International Applicants
This project is eligible for a fully funded College of Science and Engineering studentship which includes:
• A full international fee waiver for 3.5 years
• Research Training Support Grant (RTSG)

Application Instructions
The online application and supporting documents are due by Monday 21st January 2019.

Any applications submitted after the deadline will not be accepted for the studentship scheme.

References should arrive no later than Monday 28th January 2019.

Applicants are advised to apply well in advance of the deadline, so that we can let you know if anything is missing from your application.

Required Materials
1. Online application form
2. Two academic references
3. Transcripts
4. Degree certificate/s (if awarded)
5. Curriculum Vitae
6. CSE Studentship Form
7. English language qualification

Applications which are not complete by the deadline will not be considered for the studentship scheme. It is the responsibility of the applicant to ensure the application form and documents are received by the relevant deadlines.

All applications must be submitted online, along with the supporting documents as per the instructions on the website.

Please ensure that all email addresses, for yourself and your referees, are correct on the application form.

For more information, please visit our website at:
https://www2.le.ac.uk/colleges/scieng/research/postgraduate-opportunities/cse-2019/instructions