E&I Research Studentship project proposal 2019

Project title: Advanced plasma functionalisation of earth abundant electrode materials for batteries and super capacitors

Supervision Team:
Satheesh Krishnamurthy, School of Engineering & Innovation (satheesh.krishnamurthy@open.ac.uk)
Nick Braithwaite, School of Physical Sciences (n.s.braithwaite@open.ac.uk)

Project Highlights:

- Advanced functionalisation of 2D materials for low cost batteries and super capacitors for energy storage
- High end characterisation to get deeper understanding of materials
- International travel to USA, Sweden, India
- Possibility of working with Industry

Project Description:

Low cost sodium ion batteries and hybrid supercapacitors will be investigated in this project and with a view to developing nanomaterials (for domestic energy storage devices such as those employed in smart micro-grids) to replace Li Ion batteries. For example, we will investigate cathode materials such as $NaFeO_2$ and its derivatives for low cost cathode material for sodium ion batteries.

The key to good performance is not only related to composition of these systems, but also in material fabrication and design, process and depositing them through different techniques. We will therefore investigate the synthesis and plasma functionalisation and its influence to structural, electronic, electrical and morphological relationships for low cost iron based materials of the type ABO_2. B may be Fe and related transition metals and A = Na (atomic substitutions for Fe onto the B atom could be from Mg, Ti, Mn, Mo). For the electrodes in our devices, interfacing with graphene or other 2D materials will be key to improve the electrochemical properties and reduce impedance. We will employ continuous hydrothermal synthesis as well more conventional solid state synthesis (to optimise the particle size and morphology of these materials). Electrodes will be deposited via a novel route atmospheric plasma deposition route to ensure good electrical contact. The materials will be studied using a range of analytical methods such as in situ and ex situ x-ray diffraction techniques and electron microscopy in combination with electrochemical studies, X-ray photoelectron spectroscopy and NEXAFS. Access to the Diamond Light Source, Advanced Light Source in Berkeley and Stanford Synchrotron Light Source, will provide high-resolution data to analyse fully the atomic and chemical positions in these materials. Electrochemical properties will be studied using impedance and battery cycling facilities in coin cells or Swagelok cells. We will link up with a number of industry partners either directly or via EPSRC energy hubs, which will also provide a route to evaluation of any promising materials which can be scaled up and tested on larger cell sizes.

Research Methods:

Objectives:

- Investigate inorganic doped systems for Na ion batteries based on low cost oxides of iron and related transition metal oxides
- Develop and optimise synthesis methods for particle size, morphology and surface area, using low cost and scalable methods, functionalise through advanced plasma and chemical synthesis routes
- Structural, electrical and electronic property elucidations using x-rays and neutron diffraction techniques.
- Testing and optimise materials in sodium ion battery cells

- Work with industry and other partners for some scale up activity for optimised materials

Indication of project timeline:
Year 1: selection of materials and Optimisation of electrodes through plasma functionalised processes and basic characterisation
Year 2: Theoretical understanding and mechanism of electrode kinetics and interpretation. Synchrotron based measurements, conference presentations
Year 3: prototype development, manuscript writing and thesis write-up.

References

[1] Novel Hydrothermal Synthesis of CoS2/MWCNT Nanohybrid Electrode for Supercapacitor: A Systematic Investigation on the Influence of MWCNT, Aatreyee Sarkar, Amit K Chakraborty, Supriya Bera, Satheesh Krishnamurthy, The Journal of Physical Chemistry C, 2018, 122, 18237

[2] Plasma Jet Printing and in situ Reduction of Highly Acidic Graphene Oxide, Avishek Dey, Satheesh Krishnamurthy, James Bowen, Dennis Nordlund, M Meyyappan, Ram P Gandhiraman, ACS Nano, 2018, 12,5473

[3] High-power sodium titanate anodes; a comparison of lithium vs sodium-ion batteries, Yijie Xu, Dustin Bauer, Mechthild Lübke, Thomas E Ashton, Yun Zong, Jawwad A Darr, Journal of Power resources, 408, 28

Candidate Applications

- 1000 word cover letter outlining how they are equipped in their educational background and expertise to conduct the research project,
- a CV including contact details of two academic references
- An Open University application form, downloadable from: http://www.open.ac.uk/postgraduate/research-degrees/how-to-apply/mphil-and-phd-application-process (Note: This is an Advertised studentship and you do not need to submit a proposal).
- IELTs English Language test scores on application. An average of 6.5 and no less than 6 in anyone of the four components. Applicant should have these results when applying.

Applications should be sent to **STEM-EI-Research@open.ac.uk** by 28 February 2019