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Advanced Characterisation of Li and Na-ion based battery materials using Electron Microscopy

The performance, safety and lifetime of Li- and Na-ion batteries are governed by structural and chemical changes occurring at the nano- and microscale, from the quality of virgin or recycled active materials to interphase formation and failure. This PhD project aims to develop an electron microscopy toolbox to correlate these local phenomena with the electrochemical behaviour of industrially relevant technologies, focusing on graphite and hard carbon anodes and on $LiFePO_4$ and polyanionic cathodes for Na-ion systems.

Ex situ analysis of selected states of charge, calendar-aged and state-of-health cells (FIB-SEM, HRTEM, STEM-EDX) will be combined with advanced analytical and diffraction-based methods. Monochromated EELS will be used to map Li and light elements, transition-metal oxidation states and the electronic structure of electrode materials and of the SEI/CEI. 4D-STEM will provide nanoscale mapping of phases, orientation, strain and local crystallinity, including defects, Li/Fe disorder and amorphous interphases, under low-dose conditions suited to beam-sensitive materials. In situ and operando electrochemical cycling in the TEM will follow phase transformations, ion trapping, volume changes and Li/Na dendrite nucleation and growth in real time. In situ annealing will address thermal stability, phase evolution and degradation pathways, and will bridge ex situ and operando observations. The work will cover four topics: supply-chain evaluation of active materials, charge storage mechanisms, electrolyte–electrode decomposition and battery failure. The project will also include slurry and electrode processing at laboratory and industrial scales.

The project builds on my Master's thesis, a TEM/STEM study of the $NaFePO_4$, $NaMnPO_4$ and $Na_4Fe_3(PO_4)_2P_2O_7$ polyanionic cathode materials for Na-ion batteries. There I applied HRTEM, FFT/SAED indexing, STEM-EELS and EDX to polymorphism and local structure. This experience gives me a solid basis for extending these methods to operando and industrial-scale studies.

By linking academic research and industrial applications, the project aims to clarify degradation mechanisms and guide the design of materials, electrolytes and electrode processes for long-lasting, high-performance Li and Na-ion batteries.