Carbonaceous Materials for Energy Storage - Advanced Characterization.

L. Kalder 1, E. Lust 1, Y. Lu2, E. Härk2*

[1] Institute of Chemistry, University of Tartu, Ravila 14a, 50411, Tartu, Estonia; [2]Helmholtz-Zentrum Berlin, Institute of Electrochemical Energy Storage, Hahn-Meitner Platz 1, 14109 Berlin, Germany
eneli.monerjan@helmholtz-berlin.de

Advanced operando/in situ neutron and synchrotron X-ray probes are indispensable for battery research because they resolve structure–performance links in real time. Total scattering and diffraction track phase evolution and strain; small-/wide-angle scattering quantify porosity and domain sizes; imaging reveals mesoscale morphology; and spectroscopies capture oxidation states and local coordination. Together they elucidate interphase formation, redox heterogeneity, dissolution–precipitation kinetics, and degradation pathways at relevant time and length scales.[1]

Batteries play a crucial role in driving the evolution of technologies that enable the shift towards electromobility and renewable energy storage within grid systems. [2]. To meet performance and resource constraints, global efforts target new chemistries such as lithium–sulfur battery (LSB) [3] and sodium-ion battery (SIB) [4]. Carbonaceous electrodes are a primary design lever: pore topology, nanoconfinement, defect density, and heteroatom doping strongly modulate LSB cathode utilization [1,5] and SIB anode capacity [6,7] from the atomic to the mesoscale. Yet key questions remain, e.g., S_8 dissolution and polysulfide shuttling versus Li_2S nucleation/growth in LSBs, and the partitioning of Na storage among adsorption on defects, interlayer insertion, and nanopore filling in hard carbons, necessitating deeper interrogation of non-graphitizing carbons.

This presentation surveys recent advances on carbon-based anodes and cathodes using correlative, multi length scale scattering for nanostructural quantification (SANS, WAXS/SAXS), integrated with state-of-the-art electrochemical diagnostics. Emphasis is placed on real-time assessments that map pore-size distributions and phase transitions to kinetic metrics, informing data-driven design of intelligent carbon architectures that raise conversion efficiency and specific/volumetric energy.

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