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The BAM cell: an electrochemical device for operando ionic diffusion measurements using muon spectroscopy

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Understanding the complex ways that battery materials change on charging and discharging is vital for improving their function in operation, but traditional ex-situ muon measurements have barely scratched the surface of this deep mine of information. Here, we present an electrochemical cell that enables ionic diffusion measurements using muon spectroscopy (μSR) at the ISIS Neutron and Muon Source. Traditional ex-situ powder μSR measurements provide valuable fundamental properties, but they often do not investigate important ionic diffusion pathways which are only established during battery operation as charge is (de)intercalated to/from the structure. Operando experiments have the potential to follow the rate of atomic-scale ionic motion in functioning batteries, allowing the influence of structural phenomena which occur during charging/discharging, such as phase changes or lattice contractions, to be determined. The Battery Analysis by Muon (BAM) cell is described here as a simply assembled, electrochemically reliable device, which provides comparable performances to commercially available equivalent devices and can be used to study a variety of cell chemistries. The cell's suitability for μSR measurements is demonstrated by an example operando experiment on a Li-ion half cell with cathode material NMC811, which produced high quality data from the specimen of interest. This experiment outlined the benefits of μSR to follow ionic diffusivity properties during charging/discharging and uncovered a link between the material phase transitions and the measured field distribution width. Such results facilitate further development of our operando methodology, with a range of future applications of the BAM cell available for exploration.

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