Ultrasonic Phased Array Imaging of Gas Evolution in a Lithium-ion Battery

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This study presents an in-situ subsurface ultrasonic array imaging method using a phased array to detect, locate and characterize gases generated inside a lithium-ion battery (LIB). Ultrasonic signals scattered from internal gases are collected by a Full Matrix Capture (FMC) method using multiple array transmitter-receiver pairs. A subsurface cross-section image showing gases is produced by using the Total Focusing Method (TFM). The locations and distribution of the gases in both the lateral and thickness directions can be clearly revealed. The through-thickness anisotropy of the multi-layer battery structure is also considered in the imaging method which enables accurate gas detection and localization. We first conducted finite element numerical simulations to model ultrasonic wave scattering and evaluate the performance of the proposed array imaging method. The numerical results demonstrate high levels of accuracy in detecting and characterizing gases of different sizes. Subsequently, a controlled experiment using encapsulated gases inside a self-stacked battery sample is performed to validate the feasibility of the new approach in practice. Finally, a realistic long-term cycling experiment under room temperature is performed on a commercial LCO/graphite pouch cell. Multiple ultrasonic array images are produced at different cycles, and the appearance, evolution and accumulation of gases are visualized and characterized by analysing the images. The experiment findings are validated against the X-ray CT results, demonstrating that the new ultrasonic imaging method can be used to detect and monitor early-stage gas evolution inside LIBs.