Error-Aware, Layer-Resolved Characterisation of Lithium-Ion Batteries Based on Ultrasonic Resonance and Parametric Analysis

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With the prevalence of electrification in transportation and grid storage sectors, lithium-ion batteries (LIBs) are becoming one of the most fundamental energy storage elements and undergoing a profound trend of performance upscaling. The upscaled batteries demand next-level characterisation methodologies, and particularly appealing is the capability to resolve inner structural and morphological information physically, so as to identify the internal state and evolutions precisely and cost-effectively. In recent years, ultrasonic measurements have been proven as promising candidates for probing and inspecting LIBs. However, such approaches can only measure peripheral geometric features at a cell-level resolution and their characterisation performances tend to be subject to empirical configurations and sensitive to measurement conditions. To address these issues, this work reports an ultrasonic resonance-based method, featuring reliable characterisation performance, to realise layer-level robust inversion of the layered structure within LIBs. Firstly, a generalised theoretical model is introduced to capture the interaction characteristics between the ultrasound and the multilayer structure inside LIBs. By incorporating the captured characteristics into the analytic-signal procedure, a systematical framework is established to retrieve the stacking order, individual thickness, and local geometry information in a layer-resolved manner[1, 2]. Then, the relationship between the measurement parameters and the characterisation performance is analytically investigated. By considering both the temporal and spatial metrics, the performance evaluation indices are determined, with the critical measurement parameters recognised according to their physical significance. After that, the impacts of measurement parameters on the characterisation performance of LIBs are thoroughly studied by carrying out parametric analysis on the response signal simulated by the ultrasonic resonance model. Guided by such a relationship, an optimal strategy for parameter selection is developed to ascertain reliable characterisation, with its level of errors being predictable. Finally, experimental studies are carried out on different batteries with the ground truth obtained by the micro X-ray computed tomography, and the effectiveness and reliability of the proposed characterisation method are carefully validated. The proposed method demonstrates reliable performance in characterising layered structure within LIBs and could pave

the way for developing performance-informed monitoring and prediction algorithms for state of health and state of safety estimations of LIBs.

References

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