**ABSTRACT**

The lithium-ion battery (LIB) has been a powerhouse of consumer electronics for the past three decades. These applications include, but are not limited to, portable devices, electric grids, and transportation. Their staying power in the battery market is due to their being lightweight, having high energy density, long cycle life, and wide range of operating temperatures. LIBs are rechargeable, but because of the kinetics within the cell, they lose capacity due to degradation from the buildup of unwanted lithium-based byproducts. Predicting the degradation of LIBs gives users information on how long the LIB would be usable, and one parameter to determine degradation is its capacity.

Conventional data in the literature to predict future capacity comes from data associated with cycling cells. These are either current/voltage or their derivations. However, obtaining this data results in active cycling, which creates unwanted degradation. Electrochemical impedance spectroscopy (EIS) has shown recent usage to predict several cell performance metrics, including the state of health (SOH), an indicator of battery degradation, due to its non-destructive nature to the cell.

This work analyzes the different electrochemical phenomena that contribute to the impedance of a cell and their ability to predict capacity and SOH. These are analyzed using experimental EIS and equivalent circuit models (ECMs). With experimental EIS, salient regions were identified to predict capacity over a cell’s cycle life. Using LCO coin cells, the impedance at salient frequency ranges occurs in the overarching charge transfer region, consisting of the charge transfer resistance, double-layer capacitance, and the solid electrolyte interface. These phenomena were shown to predict capacity and SOH more accurately than the global EIS, including diffusion of ionic species. The ECM provides more in-depth knowledge of the parameters within the charge transfer region and their ability to predict capacity. Analysis showed that the charge transfer resistance within the charge transfer region provided the best correlation to predict capacity. These analyses revealed that characterizing a LIB for battery prognosis on its impedance does not need to include the low-correlated, low-frequency diffusion spectrum, which accounts for more than 90% of the time necessary to acquire global EIS.

Ultimately, this study provides a faster and less computationally intense method to accurately predict battery degradation via its capacity and SOH. This method can be used for battery management systems and battery testbench applications focusing on LIB capacity fade.