Abstract for oral presentation

Effect of temperature spatial non-uniformity on electrochemical impedance in lithium-ion cells

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We investigate the relationship between cell internal temperature distribution and electrochemical impedance, focusing on the variation in impedance phase shift at a single frequency in the 40-100 Hz range. This can be rapidly measured in on-board monitoring systems. Combined with a measurement of cell surface temperature and a simple thermal model, accurate estimation of maximum internal cell temperature is possible.

Studies have shown that: (1) the impedance of various types of li-ion cells at high frequencies (>30 Hz) is dominated by the anode [1], therefore impedance measurements in this range are unaffected by changes to the cathode structure; (2) the degradation of li-ion cells under normal conditions is primarily at the cathode [2], and so the anode structure may remain stable even after several thousand cycles [3]; and (3) the impedance due to the SEI layer is approximately independent of SoC, but highly dependent on temperature [1]. Therefore, impedance phase shift at a frequency in the 40-100 Hz range is directly indicative of *average* cell internal temperature [4], and with calibration it is possible to use this as a type of cell temperature measurement for the range -20 to 66°C [5]. However, previous work assumes the cells are at uniform temperature, whereas under typical operating conditions they may exhibit large internal temperature non-uniformities [6]. Therefore the temperature estimated using this technique may differ from the true maximum internal temperature.

The premise of our study is that the cell impedance is dependent on the overall temperature distribution throughout the cell. A cylindrical cell with a continuous temperature distribution in the radial direction may be approximated as a series of radially arranged volumetric elements electrically connected in parallel (Figure 1). Since impedance is a function of temperature, the impedance of each infinitesimal element depends on the temperature at that point. The overall cell impedance is thus the parallel sum of the impedances of each element.

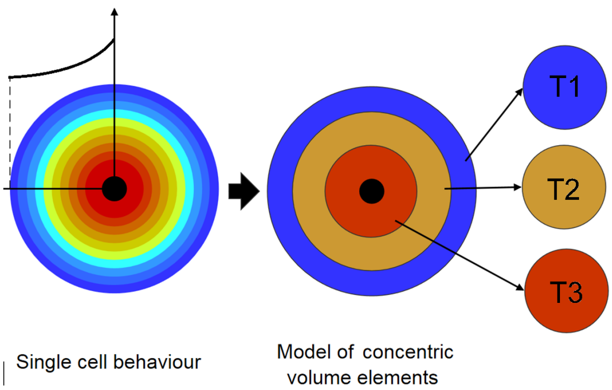

Figure 1: Cylindrical cell with continuous radial temperature distribution approximated as series of concentric elements electrically connected in parallel.

It follows from this that a phase shift measurement at a certain uniform temperature may be equivalent to that measured for a range of different temperature distributions. By using an additional surface temperature measurement in combination with the phase shift measurement, and by making an assumption about the shape of the temperature distribution based on the prior solution of a thermal model, the internal temperature distribution, and consequently the maximum internal temperature, may be estimated.

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References:

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