Characterization of battery stability through impedance characterization for Lithium-Ion Batteries

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Research question

How is battery stability (characterized by state-of-health) affected by each cycle, charging rates, and by performance in extreme temperatures for lithium-ion batteries?

Methods

The research performed on lithium-ion batteries is done through a characterization technique known as electrochemical impedance spectroscopy (EIS). There are two types of EIS, one applying current (GEIS) and one applying potential (PEIS).

Results

In Figure 1 and 2 it is possible to see the differences between the PEIS and the GEIS characterization techniques. A Nyquist Impedance Plot with the negative imaginary impedance for the battery on the vertical axis and the real impedance on the horizontal axis. The high cycling rate used for this batteries was of 3.75 C-rate. The differences between PEIS and GEIS resides in the fact that PEIS reacts to a disturbance in potential while GEIS reacts to a disturbance in current. GEIS is more precise for low impedance systems, since it is applied 10% of the rated charge current when performing it, even though GEIS and PEIS results should be equivalent.

Figure 1. Sample PEIS plot

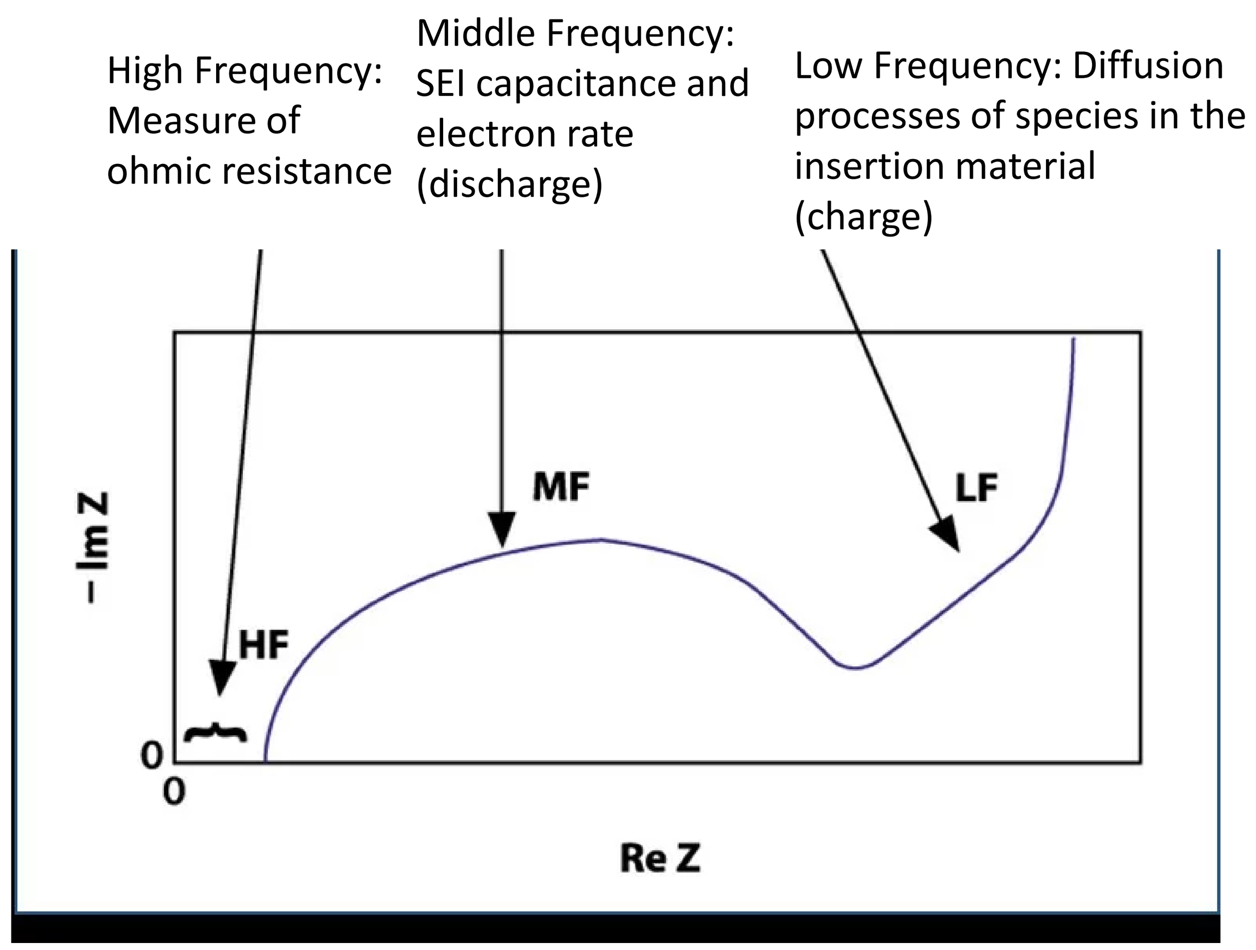
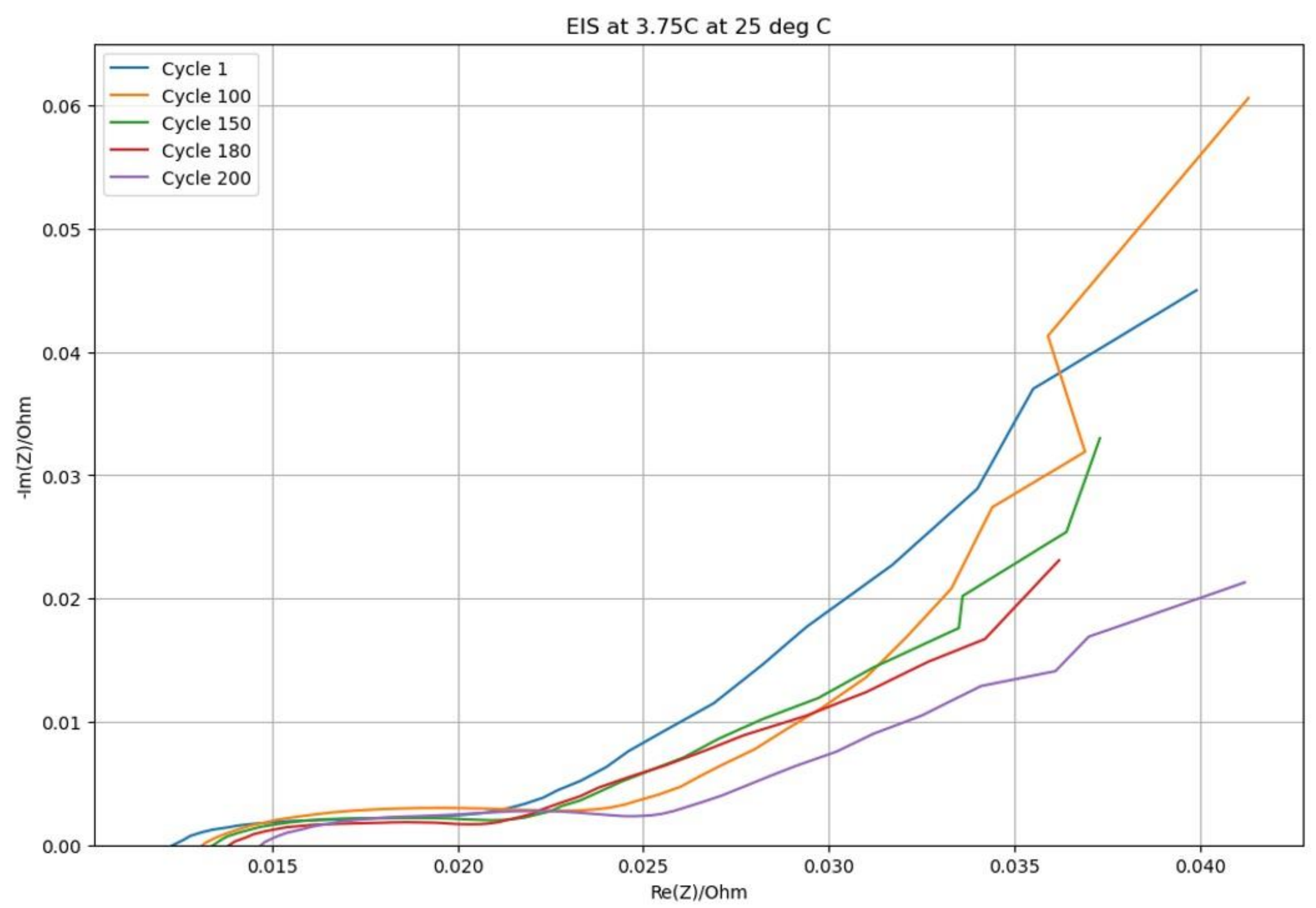


Figure 2. GEIS with high C-rate



Comparing Figure 1 to Figure 3, it is possible to observe the frequency regions for the batteries in our cycling is similar to the sample PEIS plot.

Figure 3. PEIS with low C-rate

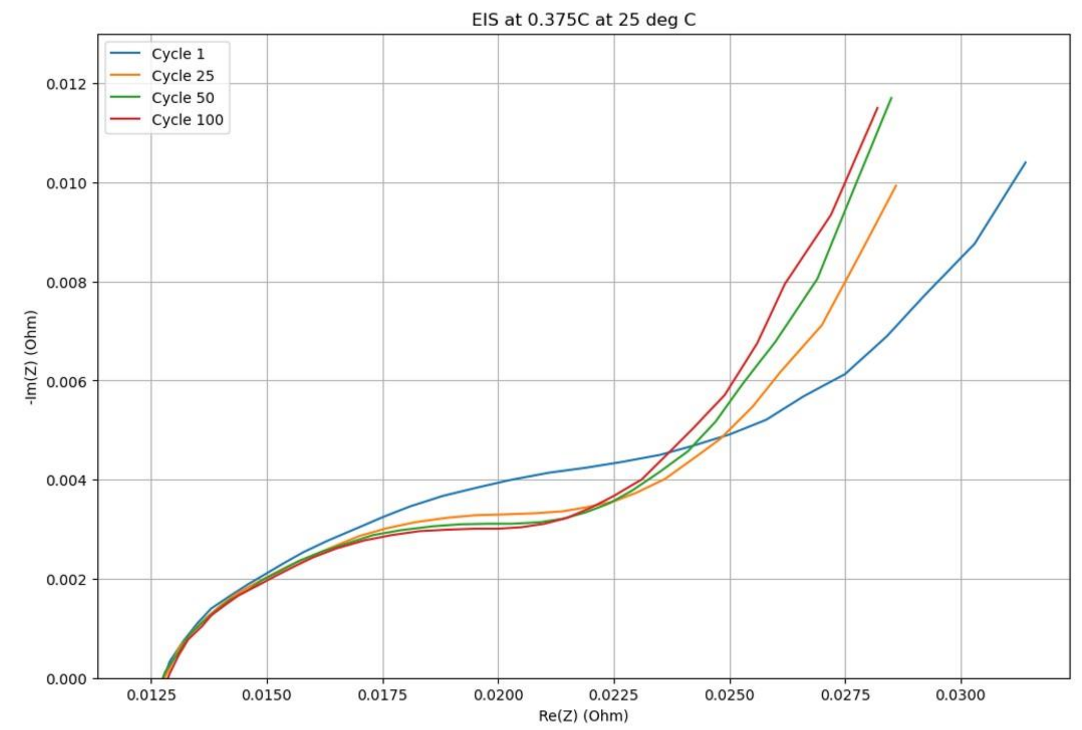
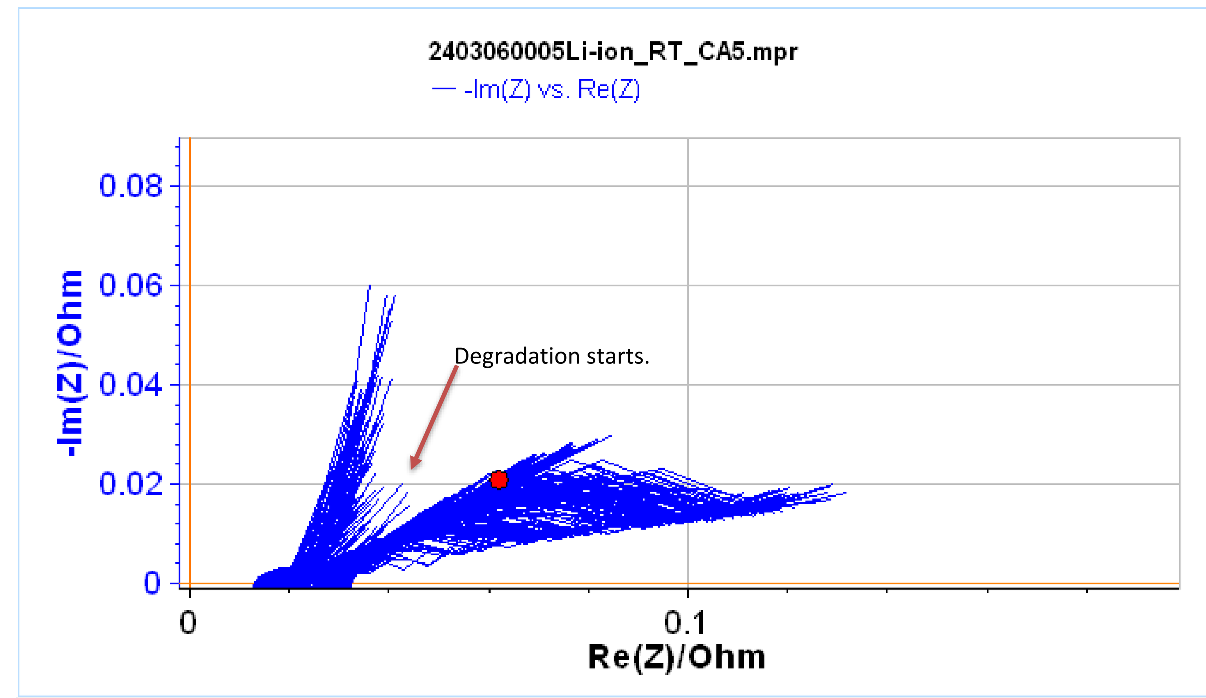


Figure 4. PEIS with high C-rate



For Figures 3 and 4 the same characterization technique is used: PEIS. The difference is that Figure 3 has a 0.375 C –rate while Figure 4 has a 3.75 C-rate. Figure 3 shows a smaller set of cycles while Figure 4 shows the complete cycling experiment. Figure 4 also shows the results of a battery that has reached failure. This can be seen in how cycle 50 for Figure 4 is further to the right on the Low Frequency section. Degradation causes the EIS to shift to the right and increases internal resistance since the battery is degraded. Ideally PEIS and GEIS results should be equivalent. Since the results here vary, the diffusion impedance region response when doing GEIS is less evident than when doing PEIS, as it can be seen in the comparison from figure 2 and figure 3, and that is why PEIS is preferred.

Conclusion

The research that is being done on the lithium-ion batteries is providing useful insight into their behavior and how it could be implemented into the second life use of batteries. The data that is being collected is also being used to develop a machine learning model that can predict the state of health for a battery based on existent data. These battery characterization techniques will also be used to characterize sodium-ion batteries, a sustainable alternative to lithium that could aid in the shortage of supply for electric vehicle batteries.

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BioLogic. (2023). Why use Electrochemical Impedance Spectroscopy (EIS) for battery research? Retrieved from: https://www.biologic.net/topics/why-use-electrochemical-impedance-spectroscopy-for-battery-research/

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