Impedance and noise as non-invasive methods for lithium metal anodes

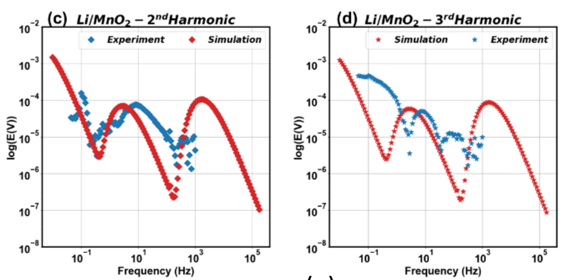
Burak Ülgüt
Department of Chemistry, Bilkent University, Ankara, Turkey

Analyzing battery performance and behavior is critical for not only designing better batteries but also in order to follow the life of electrically powered devices. With the increasing deployment of electric vehicles, being able to evaluate the real-time properties of batteries enables constant monitoring and informed decision-making regarding replacement, fast charge and other critical issues.

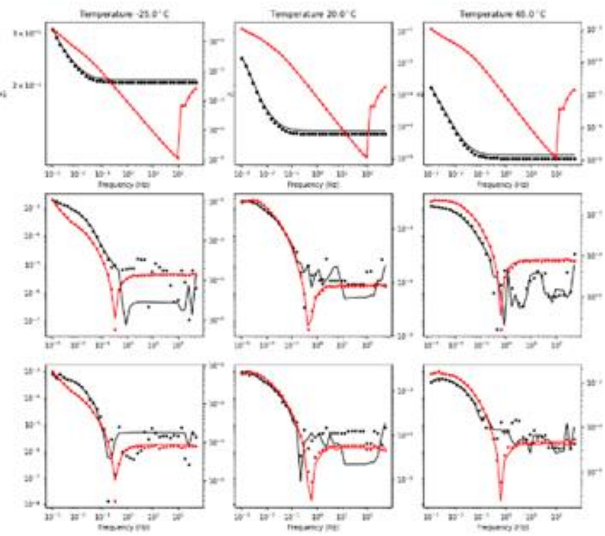
Electrochemical Impedance Spectroscopy (EIS) is a well-known analysis method that is non-invasive. Varying the frequency of the AC excitation applied to the battery under test, different interfaces are excited or by-passed. This in-turn yields electrical signatures of the various buried interfaces without physically disassembling them. Though enormously powerful, EIS is very prone to misanalysing as the equivalent circuit approach that is very commonly used does not result in unique circuits or parameters. This makes the analysis very subjective and prone to questioning. If/when properly analyzed, parameters regarding individual components/interfaces are independently obtained from a complete cell [1].

Electrochemical Noise is an analysis method that is not only non-invasive, but also non-perturbing. In this method, there is no excitation, no signals applied to the device under test. Conventionally, electrochemical noise is employed in corrosion measurements that involve stochastic modes of noise; namely, crevice and pitting. In this method, the signal is measured and analyzed for stochastic events that are not explained by simple instrumental noise or sample related drift. Applying this to batteries is not trivial due to the large magnitude drifts and small intrinsic noise [2]. However, we have successfully employed voltage noise as a predictor of uneven discharge of metallic lithium anodes in non-rechargeable Li\MnO$_2$ batteries.

In this talk, I will be presenting our recent work on EIS and Noise on battery analyses. On the EIS front, I will be introducing extensions of EIS measurements regarding temperature dependence and higher harmonics. The information that is brought in by the extra measurements of higher harmonics and the data from different temperatures allow us to be able to identify the frequencies that various interfaces correspond to and make more detailed analyses. I will present how we are making use of the harmonics and the temperature dependence in order to extract more information.



(a)



(b)

Figure 1. (a) Figures illustrating the calculated and the measured harmonics for batteries based on the initial transient.(b) Fitting the temperature dependence of first, second and third harmonics.

On the noise front, I will be presenting our earlier work showing how and why uneven discharge in lithium metal anodes increase the voltage noise. Further, I will be presenting recent studies that critically evaluates the way noise data is typically analyzed. We will show that simple mathematical manipulation of data can generate visually pleasing figures, but are of little use since subjectively manipulatable parameters end up dictating the final result. I will be emphasizing the use of proper experimental design in evaluating the noise data in order to obtain proper results.

References

[1] Zabara MA; Göçmez H; Karabatak A; Ulgut B; Journal of the Electrochemical Society,2021, 168 ,050529

[2] Uzundal CB; Ulgut B; Journal of the Electrochemical Society,2018 volume 165, issue 11, A2557-A2562

Assoc. Prof. Burak Ülgüt is with the Department Chemistry, Bilkent University. He has a PhD from Cornell University in Electrochemistry in 2007. With electrochemical measurement development experience both in academia and in industry, his current research interests are modeling and measuring electrochemical systems in non-invasive and informative manners.

Burak Ülgüt, e-mail: ulgut@fen.bilkent.edu.tr tel: +90 312 290 24 03