ApplicationNOTE

GAMRY INSTRUMENTS

A Snapshot of Electrochemical Impedance Spectroscopy

Introduction

Electrochemical Impedance Spectroscopy (EIS) is an electrochemical technique with applications in corrosion, biosensors, battery development, fuel cell development, paint characterization, sensor development, and physical electrochemistry. EIS can even be used to test the freshness of fish! (J. Food Science, **65**, 780 (2000)) The reason for this popularity is the high information content of EIS. EIS provides a more thorough understanding of an electrochemical system than any other electrochemical technique.

Why is EIS so powerful? Because the EIS experiment involves the application of a sinusoidal electrochemical pertubation (potential or current) to the sample that covers a wide range of frequencies. This multi-frequency excitation allows (1) the measurement of several electrochemical reactions that take place at different rates and (2) the measurement of the capacitance of the electrode.

For an excellent introduction to EIS, see our Basics of EIS Application Note. The Reference Section at the end of the EIS Application Note contains additional material that will be useful to you. If you have any questions on EIS, you'll find that your friends at Gamry are a wealth of information. Call our support team if you'd like discuss the theory or the applications of EIS.

New Reference Text for EIS

"Electrochemical Impedance Spectroscopy", written by two leaders in the field, was published in 2008. The authors are Dr. Mark Orazem of the University of Florida and Dr. Bernard Tribollet of the Universite Pierre et Marie Curie in Paris. It is highly recommended and is available from the Electrochemical Society.

Short Course on Electrochemical Impedance Spectroscopy

To accelerate the learning curve, you may want to consider attending the Short Course in EIS held at the University of Texas Health Science Center. Contact us directly for more information or see the course website at http://eiscourse.com/.

Checking Your Potentiostat for EIS Accuracy

Making an EIS measurement at 1 MHz (1,000,000 Hz!) requires a potentiostat designed and built by expert electrical engineers. Almost every potentiostat supplier states in the specifications that their instrument can make an EIS measurement at 1 MHz. They do not, however, specify the accuracy. We have found errors in some of these potentiostats that exceed 10%! Fortunately, it's easy to check the accuracy of an EIS measurement, as explained in our EIS System Performance Application note.

Instrumentation for Electrochemical Impedance Spectroscopy from Gamry

The electrochemical instrument for EIS consists of a Potentiostat plus special hardware to apply and measure the AC sinusoidal signals. Because of this special hardware, EIS instruments are usually more expensive than non-EIS systems and require more room on your lab bench.

Every manufacturer of EIS instrumentation makes the same measurement, but we all use different techniques. Gamry uses a unique technology called Sub-Harmonic Sampling to perform the EIS measurement. Every Gamry Potentiostat includes the electronic components for Sub-Harmonic Sampling. When the EIS300

Electrochemical Impedance Spectroscopy Software is installed the instrument can make the EIS measurement. Sub-Harmonic Sampling has several benefits:

1. Accuracy and precision are equal to or better than other EIS techniques.
2. Adding EIS to a system only adds about 30% to the price.
3. The instrumental footprint is not increased at all, saving bench space.
4. The instrumental complexity is not increased at all. There's no annoying stack of instrumentation connected with a tangled web of BNC cables.
5. Your ability to tailor the EIS measurement is not compromised.

For most (but not all!) commercial EIS systems, the instrument is controlled by software provided by the manufacturer. The design of the control software is a critical portion of the system. Because of the complexity of the EIS measurement, the software must make the measurement with no user intervention. If the software isn't properly designed, the accuracy and precision of the measurement will suffer.

Finally, if you're going to use EIS, then you have to understand that every potentiostat that you purchase may not perform EIS properly on a particular sample at a particular frequency. If you don't recognize the limitations of your potentiostat, then you may report incorrect data and that is very, very bad.

To help you understand the performance of Gamry Potentiostats, we publish an Accuracy Contour Plot for each Potentiostat. The Accuracy Contour Plot is a visual indicator of the ability of the Potentiostat to faithfully reproduce the AC waveforms in EIS at a specific frequency on a sample with a particular impedance. For an explanation of the Accuracy Contour Plot, check out our Technical App Note on the subject.

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