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Application Area: Energy

Electrochemical Impedance Spectroscopy of a Commercial Battery with different Types of Connections

Keywords

Electrochemical Impedance Spectroscopy, EIS, Li-ion battery, four-point connection.

Introduction

The way low-impedance devices, like fuel cells and batteries, are connected to a load influences their performances. The cables, in fact, have an impedance, which could be non–negligible, if not comparable, to the impedance of such devices under test (DUTs). Therefore, choosing a two– or a four–terminal connection type strongly affects the results of the measurement (e.g., electrochemical impedance spectroscopy). For a preliminary discussion, please refer to the application note AN–EC–013, on the Metrohm.com website.

In this document, a comparison of EIS results on a commercial Li-ion battery is shown. Different EIS measurements have been performed, changing the way the battery has been connected to the potentiostat. In a Metrohm Autolab PGSTAT204, the potential is measured between the RE and S leads, while the CE and WE leads carry the current signal.

In a first experiment, EIS was performed with a two–terminal sensing configuration, therefore with the RE lead connected to the CE lead, and together to the negative pole of the battery; while the WE lead was connected to the S lead, and together to the positive pole of the battery.

In the next experiment, a four–terminal sensing configuration was employed. The RE and S leads were decoupled from the CE and S leads, respectively. The RE and CE leads were connected to the negative pole of the battery, with two separated alligator clips, while the WE and S leads were connected to the positive pole of the battery, with two separated alligator clips.

In the next two experiments, the same four–terminal sensing configuration mentioned above was employed but the difference was in the length of the wires. In one case, the wires leading RE and S were extended to approx. 1 m. and in another case, the wires leading the CE and WE leads were extended to approx. 1 m.

Experimental Setup

A Metrohm Autolab PGSTAT204, equipped with a FRA32M, was used for the measurement (Figure 1).

Figure 1 – The Autolab PGSTAT204, equipped with the FRA32M.

The DUT was a commercial Samsung ICR18650-26F Li-ion battery, Figure 2.

Figure 2 - The Samsung ICR18650-26F battery, used for the tests.

Each EIS measurement has been performed at open circuit potential (OCP), and applying a sinusoidal potential signal of 10 mV amplitude, from 1 kHz to 10 mHz, with the 4 terminals, and 100 mHz in the other cases.

Results and Discussion

In Figure 3, the Nyquist plot of the DUT with the different cabling is shown.

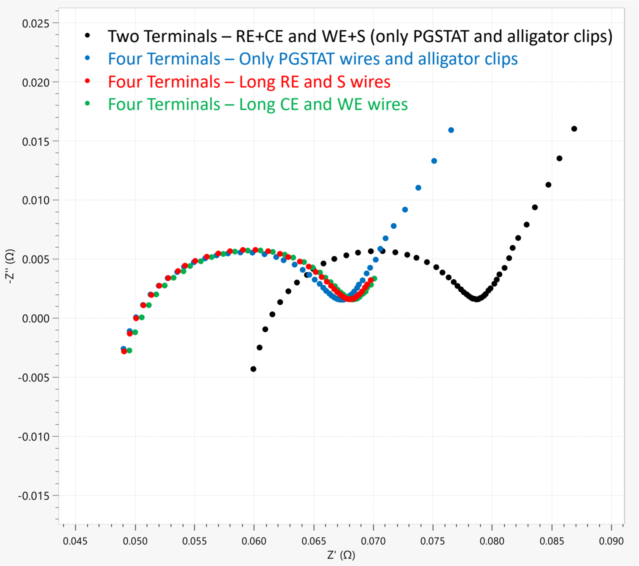

Figure 3 - The Nyquist plot of the DUT, with the different cabling. The description is in the Figure legend.

As already described in the application note AN–EC–013, the Nyquist plot of the DUT connected with a two–terminal sensing configuration is shifted towards higher impedances, of approx. 11 mΩ, with respect to the Nyquist plot of the DUT connected with a four–terminal sensing configuration. With the two-terminal sensing configuration, the RE and S leads sense the iR drop due to the current passing through the connectors and alligator clips connected to each other.

Regarding the length of the cables, the measurements made with the four–terminal sensing but without extensions (the Nyquist plot in blue, Figure 3) and with the RE and S extended (the Nyquist plot in red, Figure 3) give comparable results. This means that the length of the wires used to connect the potential sensors is negligible. This is in accordance with the fact that no current passes through these wires, therefore no iR drop is present.

In the case of the measurements made with the four–terminal sensing but without extensions (the Nyquist plot in blue, Figure 3) and with the CE and WE extended (the Nyquist plot in green, Figure 3), the latter is shifted of approx. 500 μΩ towards high impedances (the values have been calculated via interpolation of the Nyquist plot at Z' = 0 Ω). This is due to the iR drop due to the current passing through the cable and the impedance of the cable.

Conclusions

The results of the electrochemical measurements of low-impedance DUTs are influenced by the way the potentiostat is connected to the DUT. The most accurate results are obtained when a four–terminal sensing configuration is used, by avoiding any iR drop due to additional connectors or cables.

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For more information

Additional information about this application note and the associated NOVA software procedure is available from your local **Metrohm distributor**. Additional instrument specification information can be found at **www.metrohm.com/en/products/electrochemistry**.