ModuLab®
electrochemistry

Application Guide

DC cell analysis techniques
Ohmic drop measurements

John Harper and Brian Sayers
Solartron Analytical, Farnborough, UK.

Application Guide: AGML01

Introduction

Ohmic losses arising from memory effects in rechargeable batteries and from deterioration of components within fuel cells, batteries and supercapacitors severely reduce their electrical performance and cell lifetime. Research scientists attempt to quantify these effects by using current interrupt or current reversal techniques during cell cycling to measure the instantaneous change in cell voltage which is attributed to ohmic losses within the cell. The technique assumes a simple model for the cell of an equivalent series resistance (ESR) in series with interfacial impedance represented by capacitance, resistance and diffusion elements. When the current is interrupted (or reversed), the voltage across the ESR immediately changes while the voltage across the other elements is maintained for a short period due to cell capacitance. The key requirement for accurate measurement of ohmic loss is to measure voltage and current immediately after the current change and ModuLab system's high measurement rate (up to 1 MS/s) is ideal for this measurement. Having measured the voltage and current immediately before and after the current change, it is then possible to calculate the ohmic loss from [change in voltage / change in current].

This guide demonstrates how to capture data at varying acquisition rates to optimize the experimental setup allowing the scientist to evaluate ohmic losses efficiently and with a high degree of accuracy and reproducibility.

Key system capabilities used in this demonstration

- Instantaneous current reversal with up to 1 µsec time resolution
- High-speed data capture for analysis of the current reversal and voltage waveform (up to 1 MS/s)
- Reduction of data storage requirements using sample rate changes

Equipment required for this demonstration

- ModuLab electrochemical test system with Booster 2A and HV options (experiment may be run at lower current if ModuLab potentiostat only is available)
- Sealed lead acid battery - e.g. 6 V or 12 V (for example 2.5 Ah)

Connections

- Connect the ModuLab potentiostat to the battery test box or an AA rechargeable battery following the connection diagram shown in the following experiment.

Experiment setup

Select "AGML01 Ohmic Drop Measurements" in the "ModuLab Application Guide" project

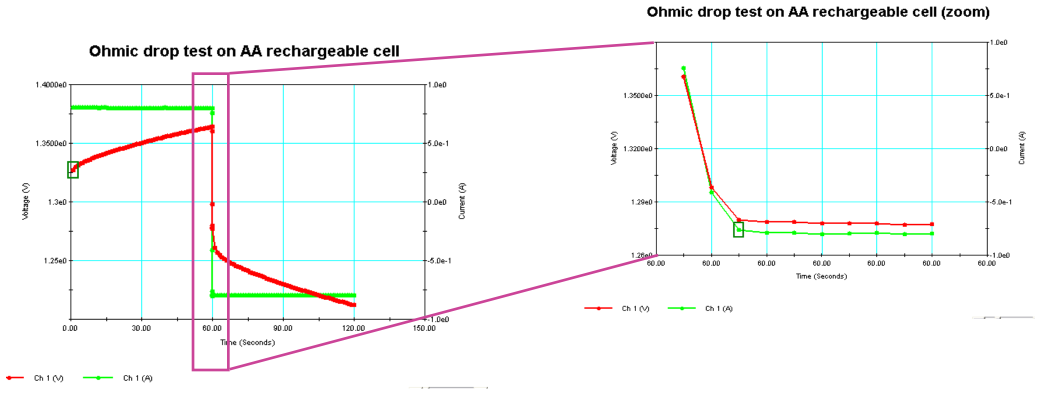
Step #	Purpose
Step 1	Charge the cell while capturing data at low rate
Step 2	Reverse the current to discharge the cell while capturing date at high rate for a short period to obtain accurate ohmic drop data after the current reversal
Step 3	Continue to discharge the cell while capturing data at low rate.

Additional test possibilities:

- Loops could be used to repeat the entire sequence for cell lifetime tests
- Impedance analysis can be added to verify ohmic losses and to investigate cell lifetime
- Analyse anode / cathode performance using auxiliary channels (voltage drop and impedance)
- Higher current levels can be run by adding external boosters

Notes on setup

It is not necessary, nor is it desirable, to acquire data at high capture rate for the whole duration of the experiment since this can quickly fill a disk drive with useless data. The data that is of most interest occurs immediately before and after the current interrupt (or reversal) step and it is this period of the experiment where high data capture rates are required. Fixed current range is used throughout the test to ensure that the range is correct immediately after the step so that no high-speed data is lost during the important step phase of the test. Loops can easily be added to repeat the charge / discharge ohmic drop sequence to examine how the ohmic drop changes as the cell becomes exhausted and eventually fails.



Data presentation and analysis

When the data from this experiment is first shown (by double clicking on the data file in the project tree) a graph showing the whole charge / discharge curve is seen. The main area of interest on this curve is the point just before and just after the current reversal. This can be zoomed into (position the mouse at one corner of the area of interest and click / drag the mouse while holding the button until the required zoom area is selected). The button is then released to zoom the graph. This procedure may be repeated several times to zoom precisely into the area of interest, as shown above. In order to achieve accurate ohmic drop measurements, it is very important to measure the voltage immediately after the current is reversed and the ModuLab system's high data capture rates allows this to be easily achieved as can be seen in the zoomed graph display showing data points at intervals of 1 μs (1 MS/s).

The ohmic drop is [change in voltage / change in current] which may easily be analyzed by positioning the cursor on the voltage and current traces immediately before and after the current reversal. In the example shown above, the rapid change in cell voltage at the current interrupt is attributed to ohmic losses within the cell and was measured to be in the order of 53 mΩ.

Conclusions

The high data capture rate and ease of selecting appropriate measurement acquisition rates makes the ModuLab system the ideal choice for the determination of ohmic losses for battery, fuel cell and supercapacitor development. An alternative measurement method for obtaining the ESR is impedance analysis which is also supported and may be used to verify ohmic drop results (a Frequency Response Analyzer option is required to perform impedance analysis).

Application Guide

solartron analytical

Solartron Analytical's Quality System is approved to BS EN ISO 9001:1994

FM01709

...part of AMETEK® Advanced Measurement Technology

UNIT B1 ARMSTRONG MALL
SOUTHWOOD BUSINESS PARK
FARNBOROUGH, GU14 0NR
UNITED KINGDOM
Phone: +44 (0) 1252 556 800
Fax: +44 (0) 1252 556 899

801 SOUTH ILLINOIS AVENUE
OAK RIDGE
TN 37831-2011
USA
Phone: +1 865 425 1360
Fax: +1 865 425 1334

Visit our website for a complete list of our global offices and authorized agents

solartron.info@ametek.com www.solartronanalytical.com

150508

15/05/2008