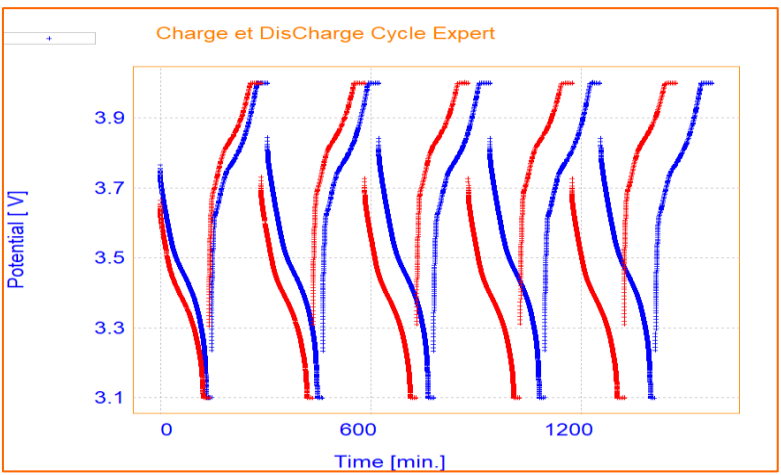
Application Note

Battery
AP-B05

Difference of 2 and 4 electrode configurations in battery studies



Generally, the electrochemical cell is connected to Potentiostat system using 3-electrode setup, but other setups are available as 2 and 4 electrode configurations. In this topic the influence of 2 electrode versus 4 electrode configurations are being studied on battery analysis.

INTRODUCTION

An electrochemical cell is usually created by placing working, reference and auxiliary electrodes into electrolyte where an electrochemical reaction of interest is taking happen. Through electrochemical reaction, chemical energy will be converted to electric current. This 3-electrode configuration is used in many applications.

Other electrochemical cells are available as:

- 2-electrode setups
- 4-electrode setups

Common usage of 2-electrode configuration in battery analysis consists of one or more such cells.

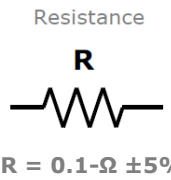
4-electrode configuration is mostly used for membrane study while this configuration is becoming more and more useful in battery research because of its influence in IR compensation.

In this application note, it is explained while the sample is a battery with an internal resistor or when a long cable is used, how 4-electrode configuration can help us to have better results rather than 2-electrode setups in IR compensating.

Figure 1: The left photo shows 2 electrode configuration and the right photo is about 4 electrode configurations with a potentiostat

Difference between 2 and 4 electrode configurations on resistance 0.1 ohm

In this method, Linear Voltammetry was performed on resistor 0.1 ohm, in two different configurations (2 and 4 electrodes). Parameters of the test is shown in figure 2.



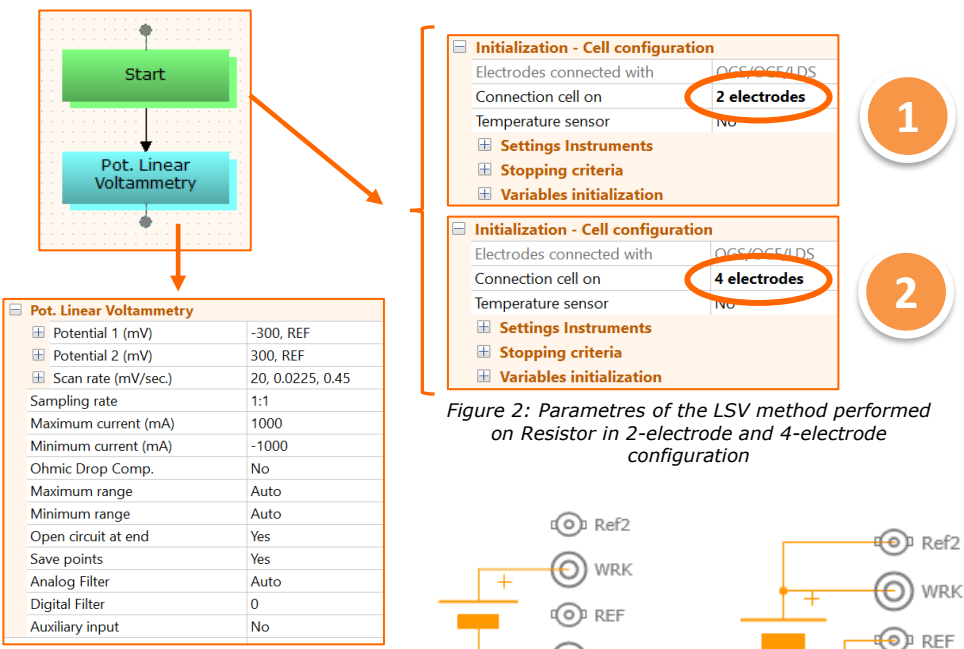


Figure 2: Parametres of the LSV method performed on Resistor in 2-electrode and 4-electrode configuration

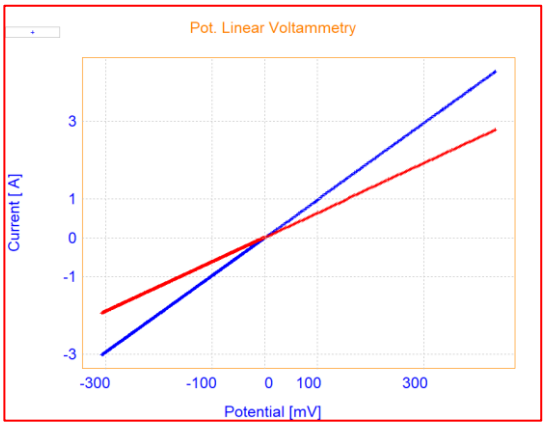
NOTE: The connections between resistor and potentiostat is like figure 1. In the "Start" sequence element, the electrode configuration should be defined.

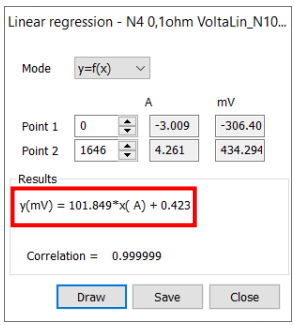
RESULTS AND DISCUSSION

Figure 3 shows the linear voltammogram of Resistor 0.1-Ω by OrigaMaster software.

Blue : 4-electrodes : cable compensation

Red : 2-electrodes : **no** cable compensation





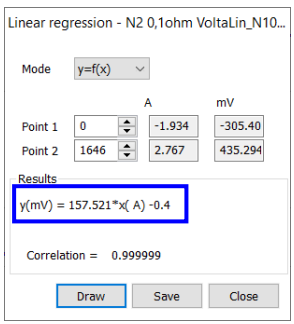


Figure 3: Linear Voltammetry of resistor 0.1-Ω with 2 and 4-electrode configurations

It can be seen from the curve that the slope of blue curve is higher than red one corresponds to this matter that the intensity of 4 electrode configuration is much higher that 2 electrode.

NOTE: The length of cords in this test were 2-m to verify better the influence of different configurations.

Difference between 2 and 4 electrode configurations on battery sample

In the second method, charge/discharge and Impedance tests were performed on Li-battery in two different configurations (2 and 4 electrodes). The battery was connected to the potentiostat with two 2-meter cords. Parameters of the test is shown in figure 4.

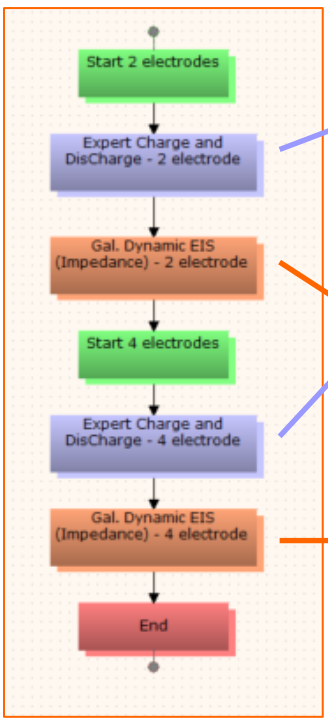


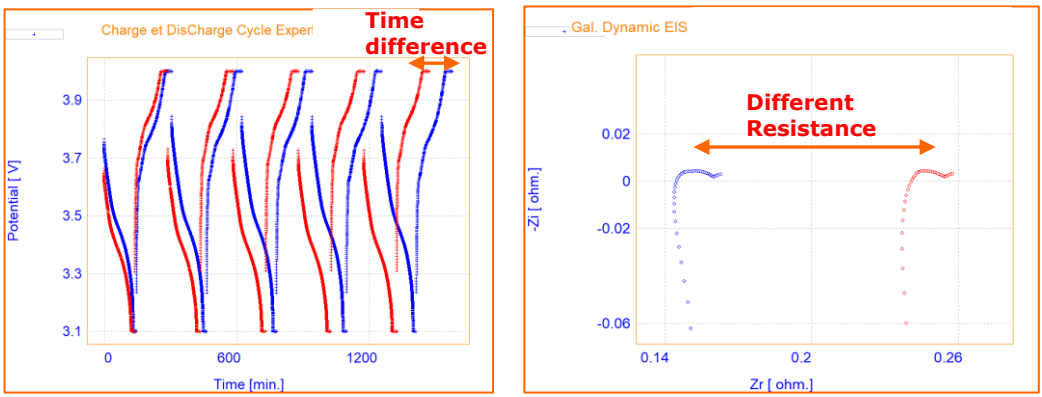
Figure 4: Parametres of the charge/discharge and Impedance tests

Expert Charge and DisCharge Cycle	
Phase no. 1	
Cycle number	1
Galvanostatic Phase no. 1	
Set Current 1	-733, mA
For Duration	5, hour
Or exit if potential is	<, 3100
Record every dt	5, sec.
Or record every dE (mV)	10
Potentiostatic Phase no. 1	
Hold potential	30, min.
Or exit if | current | <	100, mA
Record every dt	5, sec.
Or record every dQ	500, uA.h
Open Circuit Potential Phase no. 1	
Exit conditions Phase no. 1	
Phase no. 2	
Cycle number	1
Galvanostatic Phase no. 2	
Set Current 2	733, mA
For Duration	5, hour
Or exit if potential is	>, 4000
Record every dt	5, sec.
Or record every dE (mV)	10
Potentiostatic Phase no. 2	
Hold potential	30, min.
Or exit if | current | <	100, mA
Record every dt	5, sec.
Or record every dQ	500, uA.h
Open Circuit Potential Phase no. 2	
Exit conditions Phase no. 2	
Global parameters	

Gal. Dynamic EIS (Impedance)	
DC signal : Stabilisation phase	
DC Current	0, mA
Stability max duration	300
Stability criterium (mV/min.)	0
Analog Filter	Auto
AC Signal : Frequency scan definition	
Initial frequency	100, kHz
Final frequency	100, mHz
Freq. per decade	10
Frequency distribution	Log
AC sine wave amplitude zero to peak (mA)	60
Delay before integration (sec.)	0.1
Average Measurement	
Number of zones	1
Average zone 1	5, 100, kHz
Global parameters	
Real time plot	Nyquist
Open circuit at end	Yes

RESULTS AND DISCUSSION

Figure 5 shows the Expert charge/discharge and Impedance curves of Li-Ion battery 2200-mAh Emmerich, with two different configurations.



Blue : 4 electrodes : cable compensation
Red : 2 electrodes : **no** cable compensation

Figure 5: charge/discharge and impedance curves of Li-ion battery

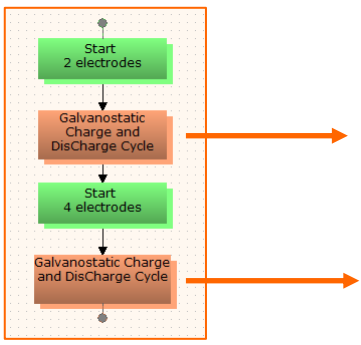
In the charge/discharge curves, it can be clearly seen in the blue curve the algorithm of charge and discharge process continue in more stable rhythm while in red curve the period of charge and discharge is becoming shorter and shorter without cable compensation.

For Nyquist curve it can be concluded that the resistance of electrochemical cell will be reduced by 4 electrode configuration while there is cable compensation.

NOTE: For more information about "Expert charge/discharge" and "Impedance" methods and their parameters, please look at application notes AP-B01 and AP-GE09 on our website: https://www.origalys.com/application-notes

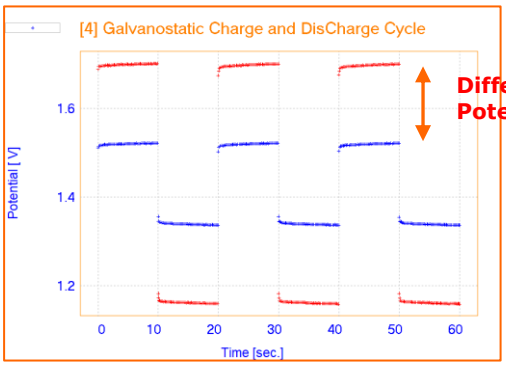
RESULTS AND DISCUSSION

Other test which were performed on the same Li-Ion battery was Galvanostatic charge and discharge. Parameters of the test is shown in figure 6.



Gal. Charge and DisCharge Cycle	
Phase no. 1	
Set Current 1	2000, mA
For Duration 1	10, sec.
Or exit if potential is	>, 1800
Phase no. 2	
Set Current 2	-2000, mA
For Duration 2	10, sec.
Or exit if potential is	<, 1100
Global parameters	
Record every dt	0.1, sec.
Or record every dE (mV)	10
Cycle number	3
Analog Filter	1 msec.
Digital Filter	0
Open circuit at end	Yes
Ordinate Y2	Current

Figure 6: Galvanostatic charge/discharge method on Li-ion battery



Blue : 4 electrodes : cable compensation
Red : 2 electrodes : **no** cable compensation

Figure 7: Galvanostatic charge/discharge curve of Li-ion battery in two different configurations

In the blue curve on figure 7 it could be seen how IR compensation reduced the potential needed for charging and discharging of battery whereas in the red curve no compensation is performed, and the potential values are higher.

INSTRUMENT AND ELECTRODES

Figure 8: Multi Potentiostat, all tests of this application note were performed on second channel

Electrode setup	
Sample Resistance	0.1-Ω
Li-Ion Battery	2200-mAh
Cords	Banana-BNC 2-m
Software	OrigaViewer 2
Potentiostat	OGF5OO

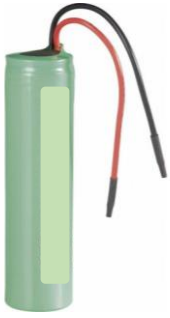


Figure 9: Li-Ion battery

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