Metrohm Autolab

Application Area: Batteries

High Voltage Measurements: Characterization of NiMH Batteries with Autolab PGSTAT302N in Combination with Voltage Multiplier

Keywords

Battery Applications: Batteries, Charge and discharge measurements, High voltage measurements, Metrohm Autolab, Voltage Multiplier

Introduction

A nickel metal hydride (NiMH) battery, is a type of rechargeable battery with has a hydrogen absorbing alloy as anode. Like in the nickel-cadmium (NiCd) batteries, nickel is the cathode. A NiMH battery can have two to three times the capacity of an equivalent size NiCd and the memory effect is not as significant.

During the discharge, at the positive electrode the following reaction occurs:

$$Ni(OH)_2 + OH^- \rightarrow NiOOH + H_2O + e^- \quad 1$$

With a standard potential of $E_c^0 = 0.490\ V$.

At the negative electrode, the following reaction occurs:

$$M + H_2O + e^- \rightarrow MH + OH^- \quad 2$$

With a standard potential of $E_a^0 = -0.828\ V$.

Applications of NiMH type batteries include hybrid vehicles and consumer electronics (flashlights, digital cameras, laptop computers).

Characterization of NiMH batteries and battery packs usually involves recording the voltage and current profiles at repeated charge-discharge cycles. These measurements can be performed either in potentiostatic or galvanostatic mode.

While a single NiMH battery has a nominal voltage of ≈ 1.2 V, NiMH batteries are usually available in packs. The voltage output of such packs is directly proportional to the number of single cells in the pack. In some cases, the total voltage can exceed the maximum of 10 V measurable by the Autolab instruments.

Experimental setup

For the experiments, a Metrohm Autolab PGSTAT302N was used.

To apply and measure voltages greater than 10 V, a voltage multiplier that increases the voltage output of the Autolab PGSTAT302N to ± 30 V was used.

The devices under tests (DUTs) were two 8.4 V – 250 mAh NiMH battery packs placed in series configuration.

The voltage multiplier were connected to the reference and the sense electrode leads of the Autolab PGSTAT302N. The voltage multiplier provides an extension of these electrode leads to the battery pack. The reference electrode lead of the voltage multiplier was connected to the negative pole of the pack, together with the counter electrode lead of the PGSTAT302N while the sense lead of the voltage multiplier was connected to the positive pole, together with the working electrode lead of the potentiostat, Figure 1.

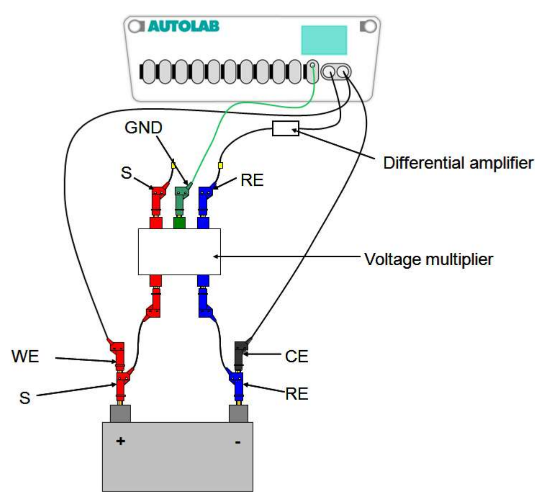

Figure 1 - Overview of the connection between the battery pack and the potentiostat

Before the experiments were carried out, the battery pack was charged with a current of 100 mA, for about 600 seconds. Three series of experiments were performed in order to illustrate the use of the voltage multiplier.

In the first series of experiments, the battery pack was charged for 600 seconds, with a current of 100 mA, then discharged using a current sweep between 0 mA and -150 mA.

The second series of experiments consisted in a repetition of constant charge (100 mA) and discharge current (-100 mA).

In the third set of experiments, the battery pack was continuously charged and discharge by applying positive and negative voltages (± 0.5 V) with respect to the open circuit potential (OCP).

The voltage multiplier can also be used to perform impedance measurements. It has to be stressed that it is possible to use it with electrochemical cells displaying a total impedance up to 100 Ω. To illustrate this, an electrochemical impedance spectroscopy was carried out, with a DC voltage of 16.8 V and an AC voltage amplitude of 0.1 V. The frequency range was between 10 kHz and 100 mHz, ten frequencies per decade.

Experimental results

DC Measurements

In Figure 2, the output voltage response of the battery pack during the discharge sweep is shown. The initial voltage (OCP) was ≈ 19 V, while the final voltage was 17.2 V, at –150 mA discharge current. This potential profile has the typical shape of the discharge profile of a NiMH battery.

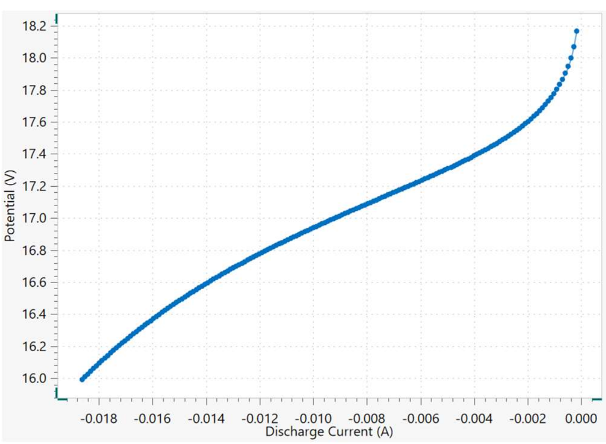

Figure 2 – Discharge current sweep from 0 mA to – 150 mA at sweep rate of 1 mA/s

Figure 3 shows the charge/discharge voltage profile of the battery pack after a series of 10 cycles. The charging current was 100 mA and the discharging current -100 mA. The output voltage of the battery reaches a maximum value of 18.6 V in the last charging step and a minimum output voltage of 17.7 V during the first discharge step.

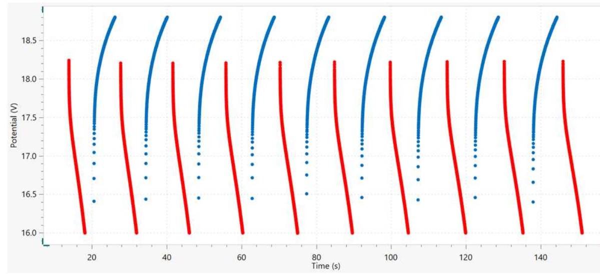

Figure 3 – Charge potential profile (blue line) and discharge potential profile (red line) of the battery pack.

In Figure 4, the current response during repeated potentiostatic charging and discharging cycles is shown. The charging voltage was +0.5 V vs. OCP, which resulted in an applied potential of 18.3 V. The discharging voltage was -0.5 V vs. OCP, resulting in 17.3 V.

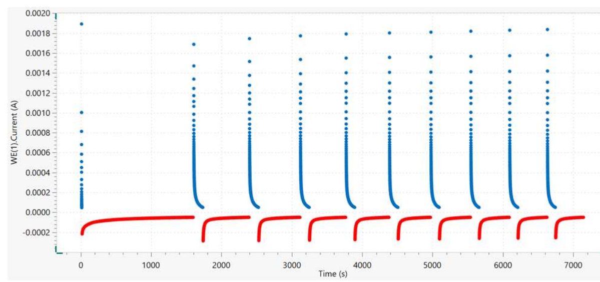

Figure 4 – Charge/discharge current profile in time (charging potential: 18.3 V, red; discharging potential: 17.3 V, blue)

AC measurements

In Figure 5, the Bode plot for the NiMH battery pack is shown. The red line corresponds to the phase angle and the blue line corresponds to the modulus (or amplitude) of the impedance.

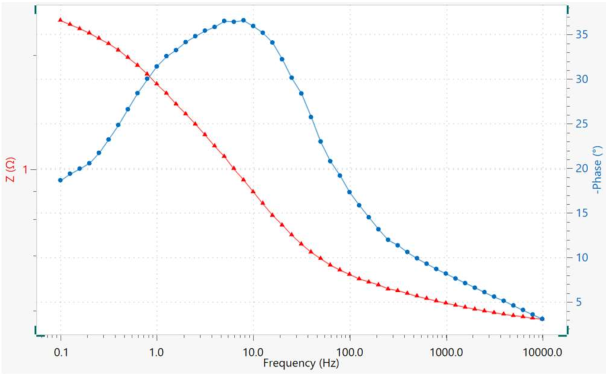

Figure 5 - Bode plot recorded at a DC voltage of 16.8 V with an AC amplitude of 0.1 V. In red, the plot of the phase angle, and in blue the modulus of the impedance

Conclusions

This application note illustrated the use of the voltage multiplier in combination with the Metrohm Autolab PGSTAT302N.

The voltage multiplier allows to increase the applied potential range of the potentiostat up to a maximum value equal to its compliance voltage, ± 30 V in the case of the PGSTAT302N. This is convenient in order to study energy storage devices that are able to deliver potentials higher than the 10 V limit. The voltage multiplier can be used both in galvanostatic mode, to measure voltages higher than 10 V, or in potentiostatic mode, to apply potentials higher than 10 V. Besides, the voltage multiplier can be used with all the available AC or DC measurement techniques.

Date

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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**.