Metrohm Autolab B.V.

Autolab Application Note BAT02

Galvanostatic charge-discharge of a Li-ion battery with Autolab

Keywords

Batteries; Galvanostatic; Charge and discharge measurements

Summary

Lithium-ion (Li-ion) batteries are one of the most important energy storage devices in the market. A typical Li-ion battery is usually composed of one or more cells. The name derives from the fact that such batteries exploit the intercalation and de-intercalation of lithium ions into the active materials at the electrodes.

Each cell contains a negative electrode, a positive electrode and an electrolyte. Each electrode contains an active material; which is the host material for lithium ions. On the negative electrode, the active material is usually graphite. On the positive electrode, the active material is normally a transition metal oxide, such as $LiCoO_2$ or $LiMn_2O_4$, together with carbon black, to enhance the electronic conduction. The electrolyte is usually a lithium salt dissolved in organic, water-free liquid solvents absorbed in a porous plastic separator.

Applications of Li-ion batteries involve, for example, portable electronics, modern (hybrid) electric vehicles and grid storage solutions.

Characterization of Li-ion cells and batteries usually involves the galvanostatic charge and discharge during various cycles.

The present application note illustrates the charging and discharging of a Li-ion battery with a capacity of 2.2 Ah at different C-rates, i.e., at different charging/discharging currents (see further in the text). Potential and current vs. time plots have been recorded and potential vs. capacity plots have been calculated.

Choice of the battery

For the experiments, an Autolab PGSTAT302N has been used, together with an Autolab BOOSTER20A. A 2.2 Ah Li-ion battery from Enix Energies, with a nominal voltage of 3.75 V and a nominal energy of 8.25 Wh, has been investigated.

Galvanostatic measurements

During galvanostatic cycling of batteries, the charge and discharge current are often expressed as a C-rate, calculated from the battery capacity. The C-rate is a measure of the rate at which a battery is charged or discharged relatively to its maximum capacity. For example, a C-rate of 1 C means that the necessary current is applied or drained from the battery to completely charge or discharge it in one hour. C-rates multiples of 1 C are also exploited. In battery research, it is common to use a C-rate of 0.1C, so to charge and discharge a battery in ten hours. Since the capacity is expressed in Ampere per hour, calculating the current necessary to charge or discharge a battery is straightforward.

In this experiment, the 2.2 Ah maximum capacity of the battery has been divided by one hour, giving 2.2 A of current. This is the current needed to completely charge the battery in one hour, starting from the completely discharged state. Alternatively, a current of -2.2 A is needed to completely discharge the battery in one hour, starting from the completely charged state. In this experiment, the battery has been cycled at 0.1 C (ten hours), 0.2 C (five hours), 0.5 C (two hours) and 1 C.

The galvanostatic charge and discharge have been performed in a potential range between 2.8 V and 4.2 V.

Capacity calculation

In order to calculate the capacity, the duration of a single charge or discharge step has been multiplied by the current applied during that step. Furthermore, the capacity values have been reported in percentage. Each value has been normalized to the nominal capacity of the battery, 2.2 Ah, and multiplied by 100.

Experimental results

Figure 1 shows the current vs. time plot, at different C-rates. It can be noticed how the absolute value of the current at different C-rates is a multiple of 2.2 A. Each Section A-B-C-B-D of the plot corresponds to a different C-rate. More in detail, the current is 0.22 A (0.1 C) in Section A; 0.44 A (0.2

C) in Section B; 1.1 A (0.5 C) in Section C and 2.2 A (1 C) in Section D.

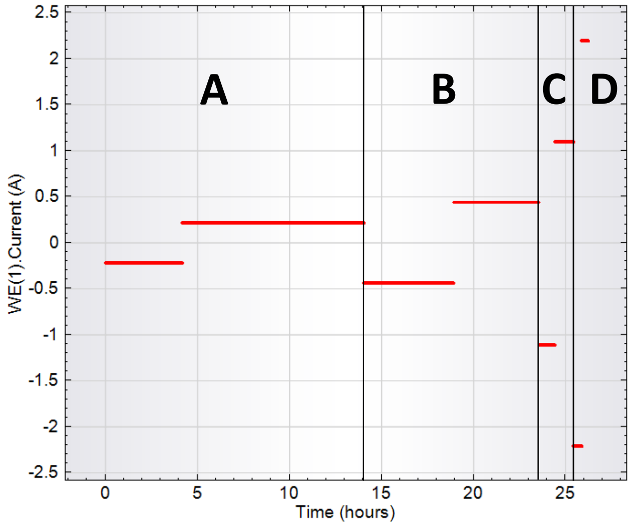

Figure 1 – Current vs. time, at different C-rates (Section A, 0.1 C; Section B, 0.2 C; Section C, 0.5 C; Section D, 1 C)

In Figure 2, the potential vs. time plot at different C-rates is shown.

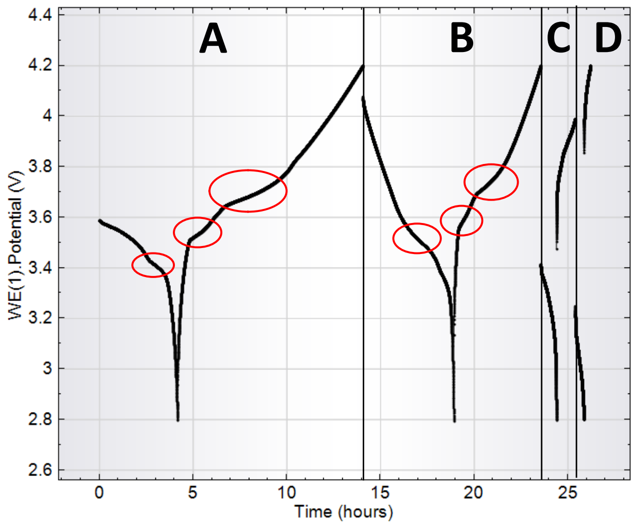

Figure 2 – Potential vs. time at different C-rates rates (Section A, 0.1 C; Section B, 0.2 C; Section C, 0.5 C; Section D, 1 C). The red circles highlight the plateaus at 0.1 C and 0.2 C

As it can be noticed, at slow charge/discharge rates, i.e., at 0.1 C and 0.2 C, plateaus (red circles) along the potential plots are noticeable. These plateaus occur at potentials where two phases, i.e., a Li-rich phase and a Li-poor phase, occur in the active material at the same time. In other words, these plateaus occur at the redox potentials of the active materials, due to Li-ions intercalation and de-intercalation.

At higher C-rates, so at 0.5 C and 1 C, the time during a charge or discharge is not enough to completely intercalate and de-intercalate the lithium ions, resulting in a charge and discharge states mostly due to polarization of the battery.

These results can be depicted more clearly in Figure 3, where the potential is plotted against the capacity at the end of each charging step, calculated as percentage with respect to the nominal capacity of the battery.

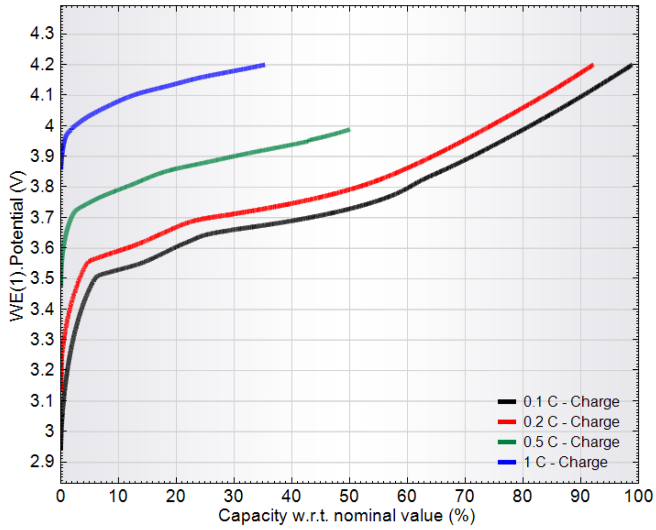

Figure 3 – Charging potential vs. capacity plot, at different C-rates

Here, it can be noticed that at high C-rates, only a small percentage of the nominal capacity is recovered. At 1 C, the capacity is the 35% of the nominal value, and at 0.5 C the capacity is the 50%. However, at low C-rate, almost all the capacity has been recovered. At 0.2 C, the capacity is at 90% of the nominal capacity and at 0.1 C almost 100% of the capacity is being recovered.

Conclusions

This application note has illustrated the possibility to test a Li-ion battery with the Autolab PGSTAT302N in combination with the BOOSTER20A. With the NOVA software, it was possible not only to plot the current and potential vs. time, but also to calculate the battery capacity, so to have a clearer picture of the state of the battery during different cycling procedures.

Date

10 April 2014