Application Note

VersaStudio - Differential Voltage and Capacity Analysis

Application Note DVDCA1

Introducing new features of VersaStudio software regarding DVA differential voltage analysis (dV / dQ), and DCA differential capacity analysis (dQ/dV), which are indispensable for battery analysis.

In recent lithium-ion batteries, metal oxide materials such as NMC and LCO are used for the positive electrode, and graphite is used for the negative electrode. Unlike lead-acid batteries, such lithium-ion batteries operate by "intercalation" and "deintercalation" in which lithium ions enter and leave the positive and negative electrodes during the charge / discharge process. Cycling over a period of time introduces cell degradation and gradual lowering of battery capacity. Standard I-V measurements collected during cycling may be used to calculate differential capacity / voltage data that is used to study cell degradation phenomena, as well as provide insight into future cell behavior. However, specialized low noise / high resolution test equipment together with use of data averaging techniques is needed to be able to extract useful information from the data.

When the battery is charged and discharged, the amount of lithium ions in the electrode increases or decreases due to intercalation and deintercalation, and the electrochemical potential of the electrode changes. The change in electrochemical potential depends on the electrode material. For example, graphite has a flat potential profile and LCO has a gradually changing potential profile as the amount of lithium ion inserted increases.

The shape of the potential profile is associated with the phase transition of the material. When dV / dQ, which is the change in potential divided by the change in charge, is plotted against the charge, peaks in the dV / dQ curve correspond to phase transitions in the electrode.

In order to evaluate the change in the electrochemical potential of the positive and negative electrodes of the battery, it is necessary to introduce a reference electrode into the battery and measure the potential of the positive and negative electrodes with respect to the reference electrode. However, since it is not easy to construct a three-electrode battery cell, a bipolar cell without reference electrode is often used.

As a result, the potential difference between the positive and negative electrodes will be measured during charging and discharging of the bipolar battery cell. By dV / dQ analysis, it can be inferred whether the change in the potential difference is caused by the positive electrode or the negative electrode. However, to do this, it is necessary to create and measure half cells in advance and obtain the potential profile of each electrode, to properly understand the data from the bipolar cell.

When the battery degrades, the size and position of peaks in the dV / dQ analysis change (corresponding to phase transitions), and that enables determination of the degradation mode. Trends can easily be seen by overlaying data from a number of charge / discharge cycles.

Measurement Setup

Measurement settings and example results are shown below. Due to the very small changes being measured, it is very important to use very low noise, high resolution (24-bit measurement) test equipment. Differentiation accentuates noise in the data, and it is therefore also important to use sliding average analysis techniques to extract useful peak information from the noise.

- Measuring instrument PMC-200
  - Voltage range: 10V
  - Current range: 2µA to 1A
  - Voltage / current resolution: 24bit
- Software VersaStudio Version 2.62.2
- Measurement target:
  - Lithium-ion battery
  - Capacity: 3000mAh
  - Shape: Cylindrical (21700)
- Measurement Step, Constant Current Charge at 1/25 C rate (120mA)
- Data Analysis:
  - Y-axis setting: Display range 0 - 100n
  - Averaging settings: 20 Point Sliding Average

PMC Test System

4T Connections to cell anode and cathode

Actions to be Performed:

Common
- Energy Open Circuit
- CC-CV
- Energy Open Circuit
- Constant Current
- Energy Open Circuit
- Constant Current
- Energy Open Circuit
- Constant Current

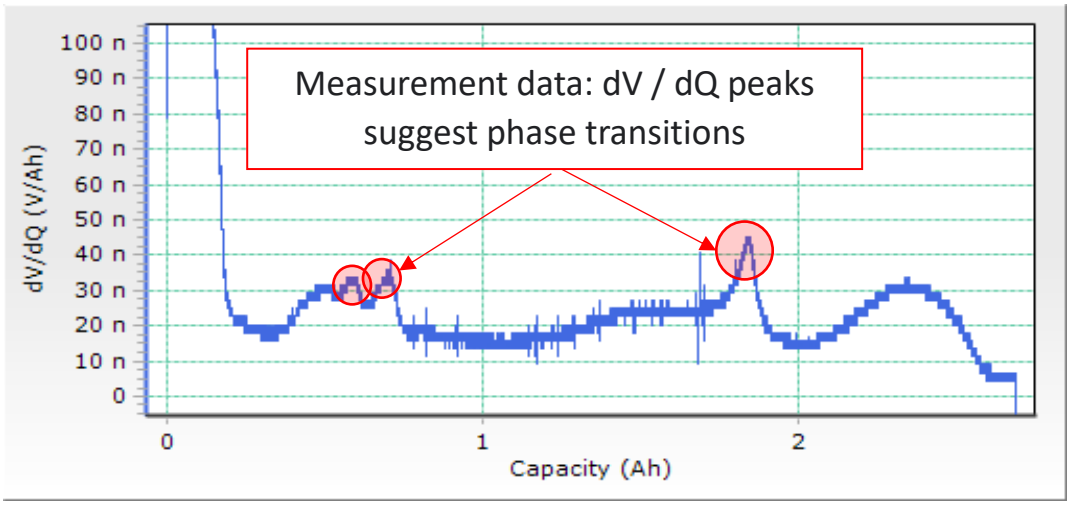
Properties for Constant Current

Step Properties	Value
Current (A)	0.12

Scan Properties	Value
Time Per Point (s)	1
Duration (s)	90000
Delta Resolution	10
Delta E (mV)	0
Delta Q (mAh)	0
Min. Total Points	90000
Max Total Points	90000

Instrument Properties	Value
Voltage Range	+/-6V
Acquisition Mode	Average
Electrometer Mode	Differential
E Filter	Auto
E2 Filter	Auto
I Filter	Auto
Bandwidth Limit	Auto
LCI Bandwidth Limit	Auto

Limits	Direction	Value
Potential(V)	≥	4.1
None	≤	0



Summary – With care, using high resolution / low noise test equipment, it is possible to extract meaningful dV / dQ information from constant current coulometry tests that informs the battery's present state of health and provides insight into likely future degradation and possible safety concerns.

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