Autolab Application Note SC01

Supercapacitors: Principles and Characterization using Autolab

Keywords

Supercapacitors; Ultra capacitors

Summary

Supercapacitors (also known as ultracapacitors, electrochemical capacitors, or double-layer capacitors) are electrochemical devices that have the ability to store and release charge and deliver high power densities over short periods of time. Their ability to store electrical energy efficiently and release electrical energy very quickly make them ideally suited for applications where short time backup power and peak power needs are critical.

Principle of a Supercapacitor

Figure 1 shows the working principle of a supercapacitor.

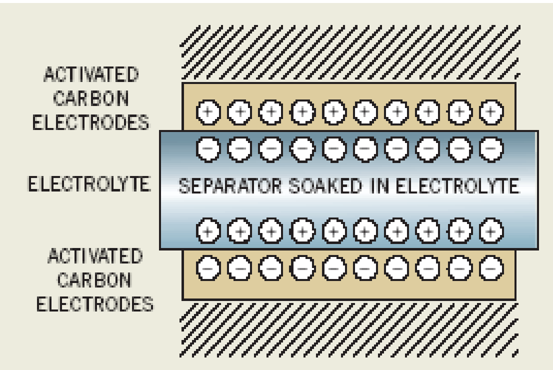


Figure 1 – Working principle of a supercapacitor

Like conventional parallel plate capacitors, they consist of two electrodes separated by an electrolyte. Capacitance increases with the increase with the surface area and the decrease in the distance between the two plates. Supercapacitors improve on conventional capacitors in two important ways:

- They work on the principle that a double layer is generated when a voltage is applied to electrodes in an electrically conducting liquid (electrolyte). The charge separation occurs in molecular dimensions (few nanometers) resulting in extremely large capacitance
- The activated carbon electrode material used has enormous available electrode surface area (2000 m^2/g).

This results in small devices with capacitances of few thousand Farads.

Supercapacitor challenges

The maximum voltage that can be applied to the electrodes is limited by the dissociation voltage of the electrolyte. The use of an aqueous electrolyte limits the voltage to about 1V while electrolytes based on organic solvents allow dissociations voltages up to 2.5V.

The high energy content of supercapacitors originates from the extremely high specific surface area and short distances between electrodes. New materials such as Carbon nanotubes, conducting polymers are being developed to increase the capacity and efficiency of supercapacitors.

Electrochemical characterization

The performance of a supercapacitor is determined by measuring its capacitance (which can vary with the applied potential) and equivalent series resistance (ESR). These can be measured by charging it at constant current and monitoring the potential response (Chrono Potentiometry), applying a potential pulse and monitoring the current response (Chrono Amperometry) or with Electrochemical Impedance Spectroscopy (EIS).

In this section the three characterization methods are illustrated with the AUTOLAB PGSTAT302N/FRA2 potentiostat/galvanostat system in combination with Booster 10A.

Chronoamperometry

50 mV and 2 V pulse were applied and the current was recorded for 30 seconds.

Assuming a pure RC circuit for the capacitor, the ln(i) plot will give a straight line according to:

$$i = \frac{\Delta E e^{\frac{-t}{RC}}}{R}$$

$$ln(i) = ln\left(\frac{\Delta E}{R}\right) - \left(\frac{1}{RC}\right)t$$

The results for 50 mV pulse are shown in Figure 2.

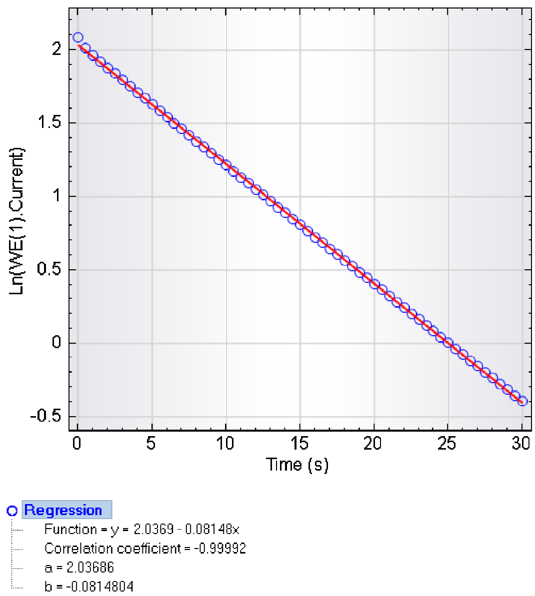


Figure 2 – Results of Chrono amperometry measurements at 50 mV on Siemens supercapacitor

Chronopotentiometry

An empty capacitor was fully charged with a constant current of 10A, while recording the potential (Figure 3). Using the relation V=Q/C, one can calculate the capacity from 1/slope of the plot.

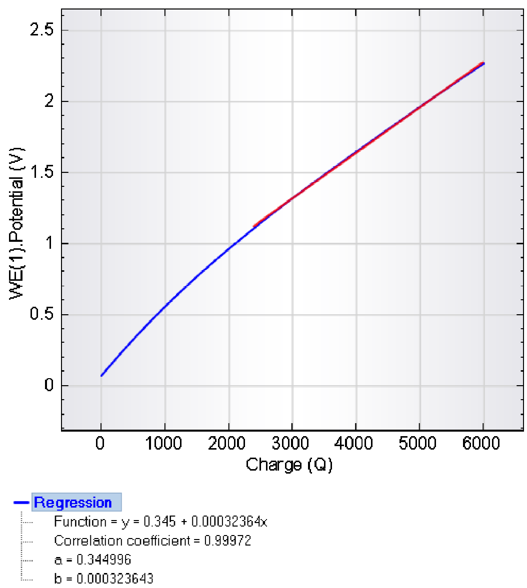
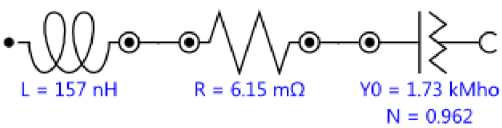


Figure 3 – Results of Chrono potentiometry measurements on Siemens supercapacitor

Electrochemical impedance spectroscopy

Impedance measurements were done at 0V and 2 V. The following equivalent circuit model was used to fit the data. The results for 0 V are shown in Figure 4.



The results the fitting of the data are shown in Figure 5.

Table 1 provides a summary of all the experimental data. The differences between the results obtained using chrono method and EIS arise due to the accuracy of the different techniques.

	C (F)		ESR (mΩ)	
Potential (V)	0	2	0	2
Chronoamperometry	1875	3185	6.55	6.33
Chronopotentiometry	1923	3249	-	-
EIS Potentiostatic	1934	2791	6.2	6.6

Table 1 – Summary of Chrono amperometry, potentiometry and EIS measurement results

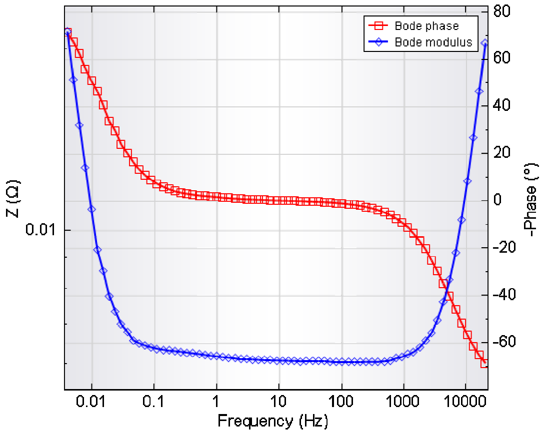


Figure 4 – Results of EIS measurements at 0 V on Siemens supercapacitor

Circuit Report

File Edit

Element	Parameter	Value	Estimated Error (%)
L1	L	1.5659E-07	0.927
R1	R	0.006154	0.305
Q1	Y0	1733.7	1.826
	N	0.96247	0.577
	χ^2	0.032959	

Figure 5 – Summary of the fitted values obtained from the impedance spectroscopy data

Date

1 July 2011