

Study of the Electrochemical Performance of Activated Carbon Bulky Paper Electrode for Electrical Double Layer Capacitor (EDLC)

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Abstract. Supercapacitor have attracted much attention due to its fast power supply, long cycle life, simple principle, etc. Supercapacitors are widely used in consumer electronics. Activated carbon is a typical material for electric double layer capacitor. Here, we study the electrochemical performance of an activated carbon (TF-B520) bulky paper electrode made by vacuum filtration method. Cyclic Voltammetry and Constant Current Charge/Discharge were used to test the electrode capacitance and the rate performance. The results showing that TF-B520 activated carbon bulky paper electrodes have the highest capacitance of 120F/g at scan rate 1mV/s and good capacitor behaviour at scan rate below 20mV/s and current density below 250mA/g.

1. Introduction

Reducing fossil fuel consumption and the effects of greenhouse gas emissions into the atmosphere has become global objectives being recognized as an imperative for the sustainable development of economy and society. [1-3] There is an urgent need for efficient, clean, and sustainable sources of energy, as well as new technologies associated with energy conversion and storage. Electricity production from renewable energy sources and further improvement of energy efficiency are the most promising solutions to reach these objectives. [4,5] Supercapacitors, also known as electrochemical capacitors or ultracapacitors, have attracted much attention because of their fast power supply, long cycle life, simple principle, and high dynamic of charge propagation. Currently, supercapacitors are widely used in consumer electronics, memory back-up systems and industrial power and energy management. on the basis of the energy storage mechanism, supercapacitors can be classified into electrical double layer capacitor (EDLC) and pseudocapacitor. [6-8] For electrical double layer capacitor (EDLC), the capacitance comes from the pure electrostatic charge accumulated at the electrode/electrolyte interface, therefore it is strongly dependent on the surface area of the electrode materials that is accessible to the electrolyte ions. [9] Activated carbon is one of the most widely used material for electrical double layer capacitor, because of its high surface area and low cost. In this article, we study the electrochemical performance of a kind of activated carbon form MTI, TF-B520, the activated carbon was first mixed with Multi-walled carbon nanotubes (MWCNTs) to increase the conductivity, and then made into a free standing bulky paper by vacuum filtration method, cut into



free standing electrodes, and finally assembled into a symmetrical electrical double layer coin cell for electrochemical measurements.

2. Experimental

TF-B520 activated carbon (from MTI) and MWCNTs (MTI) were used to assemble bulky paper electrodes. Weighing TF-B520 activated carbon and MWCNTs and mix those two materials into a clean and dry vessel with a mass ratio 2:1 (TF-B520: MWCNTs). Suspended into butanol at a dispersion concentration of 600mg/L; Sonicate for 6 hours at a room temperature. Take 100ml of this hybrid dispersion, add butanol to 400ml and continue sonication for 30min. Vacuum filtration method was used to sediment the mixed materials and get a bulky paper after 1.5 hours. Further treatment was done by vacuum drying for 24h to remove the butanol and water left inside. Weighing the final bulky paper and cut it into small pieces (6mm). The total amount is 58.9mg and each electrode is 4mg.

The electrochemical measurements were performed in a 2025 type coin cell configuration with two symmetric electrodes with same mass loading and same area, LiPF₆ in PC was used as electrolyte and glass microfiber filter as separator. Cyclic Voltammetry and Constant Current Charge/Discharge were performed in Arbin 2000.

3. Results and discussion

Cyclic Voltammetry testing on super-capacitor cells assembled with TF-B520/MWCNTs was done to analysis it's electrochemical performance. Figure 1 shows the CV test results of the cell assembled with TF-B520/MWCNTs. Where the Capacitance was calculated according Eq.1:

$$C = \frac{Q}{Um} = \frac{It}{Um} = \frac{I}{(U/t)m} = \frac{I}{vm} \quad (1)$$

Where I is the test current (A), v is the scan rate (A/s), m is the mass of one electrode (g).

At a low scan rate of 0.001V/s, 0.002V/s, 0.005V/s, CV curves assume a rectangular shape, characteristic of good double layer performance. When the scan rate is 0.02V/s, CV curve is non-rectangular, which means the series resistance in cell behaviour becomes more obvious. At a scan rate 0.05V/s and above, the super-capacitor cell shows a completely resistive behaviour.

The difference behaviour of the cell's specific capacitance assembled with TF-B520/MWCNTs at different scan rates is summarized in Figure 2, where the specific capacitance were calculated by Eq. 2, from the integral of discharge half cycles of CV curves.[10]

$$C_{sp} = 2 \frac{\int Idv}{vVm} \quad (2)$$

The specific capacitance decreased to 66.4% when the scan rate increased from 1mv/s to 10mv/s. At a scan rate of 20mv/s, its 48.5%, when the scan rate is 0.1V/s, it's only 8.3%. The specific capacitance is almost zero at a rate above 0.2V/s.

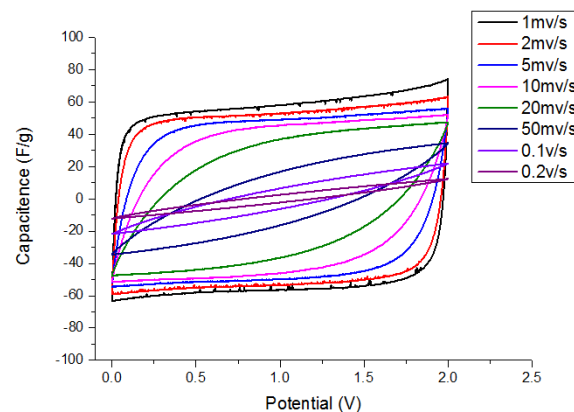


Figure 1. Cyclic Voltammetry of TF-B520/MWCNTs bucky paper based capacitor cell

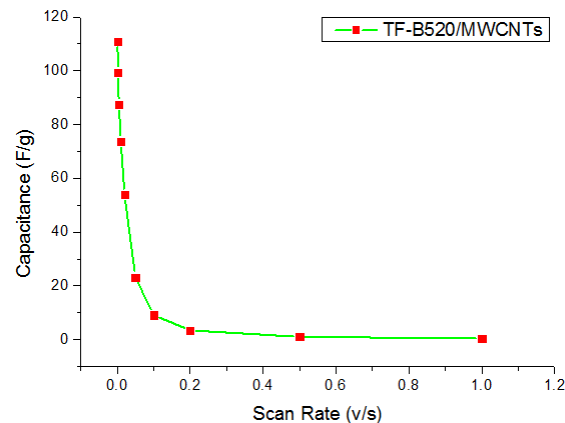


Figure 2. Specific capacitance of TF-B520 electrode in different scan rate

Constant Current Charge/Discharge (CCCD) testing is the most widely used method for the characterization of Super-capacitors under direct current. The vertical drop in voltage at the beginning of the discharge curve (IR drop) shows the cell's resistive behaviour. The CCCD test of SCs assembled with TF-B520/MWCNTs is showed in Figure 3. At low current densities (0.025, 0.05 A/g), the potential drop is < 0.1V, the electrodes exhibit a low resistance; at a current density of 0.25 A/g, the IR drop is 0.25 A; at 0.5 A/g the drop increases to more than 0.5V that the total capacitance is negatively affected.

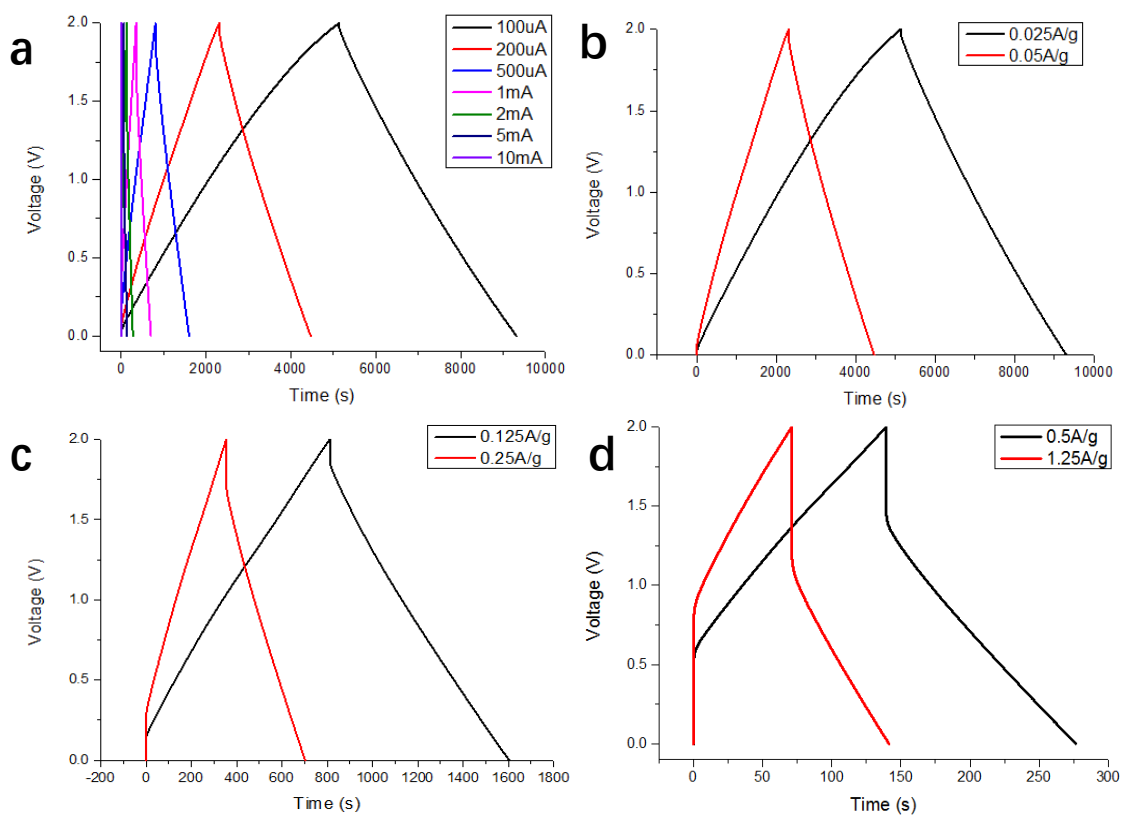


Figure 3. Constant current Charge/Discharge test of TF-B520/MWCNTs electrode in different current

The specific capacitances of one electrode at different current densities were calculated according to Eq. 3, using the discharge curve.[11]

$$C_{SP} = \frac{I\Delta t}{\Delta V m} \quad (3)$$

Where C_{sp} is the specific capacitance of one electrode (F/g); I is the current of the discharge curve(A); m is the mass of one electrode(g); $\Delta V = V_{max} - V_{IR\ drop}$ (V). The specific capacitance decreased fast to 38.6% when the current density is up to 2.5A/g.

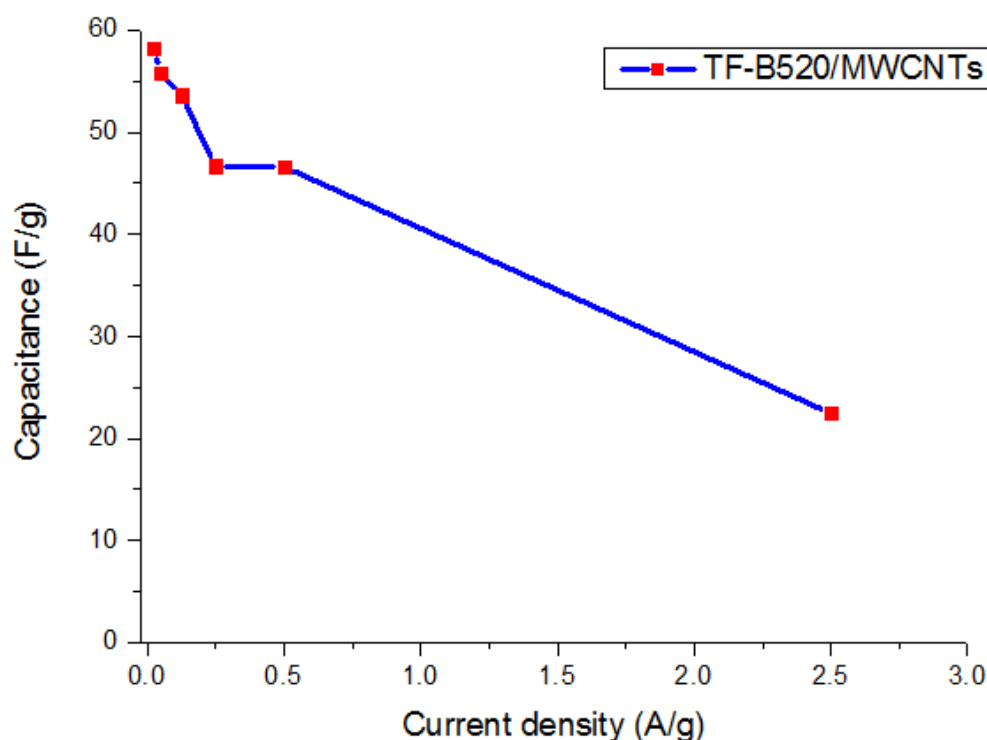


Figure 4. Specific capacitance of TF-B520 cell in different current

The difference behaviour of the cell's specific capacitance assembled with TF-B520/MWCNTs at different current density is summarized in Figure 4, showing that at low current of 0.025A/g, the EDLC cell has the highest specific capacitance of 60F/g, when the current density increase, the specific capacitance will decrease, at high current density 2.5A/g, the cell capacitance is 23F/g.

4. Conclusion

Activated carbon (TF-B520) bulky paper electrode was successfully assembled, and electrochemical behaviour of the electrode was studied by Cyclic Voltammetry and Constant Current Charge/Discharge. The results show that TF-B520 activated carbon bulky paper electrode has a high capacitance of 120F/g at 1mV/s, good capacitor behaviour at scan rate below 20mV/s and current density below 250mA/g. This work shows that the activated carbon TF-B520 can be a good candidate for commercial super-capacitor.

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