

Carbon-Based Supercapacitor Test Cell Assembly Optimization

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Introduction:

Electrochemical double-layer capacitors (EDLCs), also called “supercapacitors,” are an important component for energy storage technology due to their high power densities, yet their energy densities are less than those of most batteries [1]. As stated by the Office of Basic Energy Sciences, advances in electrical energy storage technology are critical to meeting future energy demands [2].

Our project focused on optimizing the assembly process of a test cell for developing EDLCs. Using a two-electrode cell design with activated carbon[3] and an organic electrolyte, it was found that in initial measurements the assembled cells met the specific capacitance and power density goals, however this capacitance degraded rapidly after a few hundred cycles. We outlined alterations for drier assembly, which showed some improvement under electrochemical testing, but still demonstrated a decline in capacitance. Ongoing research seeks to determine the mechanism of degradation and attempts to improve reliability of the cell.

Experimental Procedure:

The test cell design outlined in Figure 1 incorporated several commercial materials, including mylar sheets as shims, aluminum metal current collectors, and separator film. For optimizing the assembly process, we began by using activated carbon as our electrode material. The activated carbon was mixed with 3% by weight polytetrafluoroethylene as a non-conductive binder. As attempts to mix solid polymer with the carbon were unsuccessful, the binder in both versions of the method was added in an aqueous solution (20% by weight H₂O) and mixed evenly. The material was flattened to a nominal thickness of 80 μm, cut to shape, and weighed. These electrodes were then placed under low vacuum and dried at 100°C.

The electrolyte was 8M tetraethylammonium tetrafluoroborate in acetonitrile. In the proposed dry method, the salt sample was heated under vacuum at 100°C prior to mixing the solution. After immersing the electrodes in electrolyte for 12 or more hours, the test cell was assembled (see Figure 1). Un-optimized assembly allowed the test cell to be assembled in open air, whereas our dry method involved dry box assembly under nitrogen flow, where humidity was maintained near zero. Electrochemical tests were performed using the Autolab cyclic voltammeter and frequency response analyzer. Capacitance was determined using the formula in Figure 2.

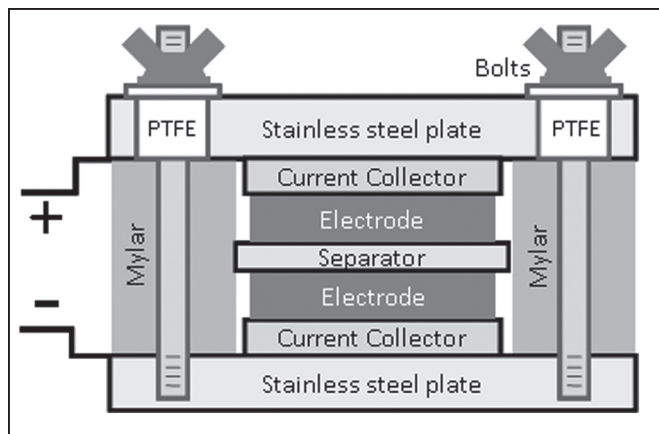


Figure 1: Diagram of two-electrode cell [4].

$$C = 4 * I \div [(V/s) * m]$$

Figure 2: Equation for capacitance. *I* represents current, (*V/s*) is the scan rate (volts per second), and *m* represents the mass of the electrode materials.

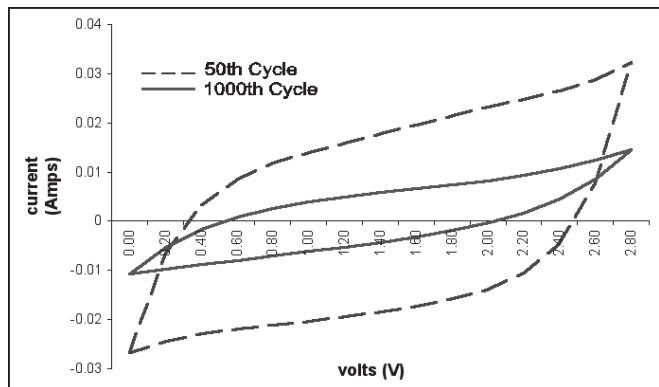


Figure 3: Cyclic voltammogram comparison of 50th and 1000th cycles in an unoptimized test cell.

Results and Conclusions:

Figure 3 depicts a cyclic voltammogram of an un-optimized test cell. While initial cycles recorded high values for current, for which a capacitance of 100 F/g was calculated, after 1000 cycles this value was greatly reduced. We proposed that this observation was due to water contamination in the electrolyte, which led to our development of the dry assembly method. The decline in average capacitance from the un-optimized method under long-term testing was compared with that of the drier method and is presented in Figure 4.

It should be noted in Figure 4 that the initial average current is higher in the un-optimized test cell, however this may be due to slight differences in the masses of activated carbon in the electrodes or variations in the concentration of the electrolyte. Of particular importance is that, while both plots show a general decline in average current throughout the course of testing, the dry-method test cell had a longer cycle life. Comparison of the data also showed the sharp drop-off observed near 700 cycles during prior testing was not present in the drier assembly test, generating linear decline.

Future Work:

As the results indicated an improvement, especially in regard to the linear character and rate of capacitance loss, we will continue to use drier assembly methods for the test cell and seek further improvements upon the method. We will also continue to seek out a non-aqueous binder for the electrodes. We will also address other potential sources of degradation, such as material failure and shorts in the circuit. Should the issue of capacitance loss be minimized, the test cell will be more effective for testing the cycle life of new materials in the electrodes.

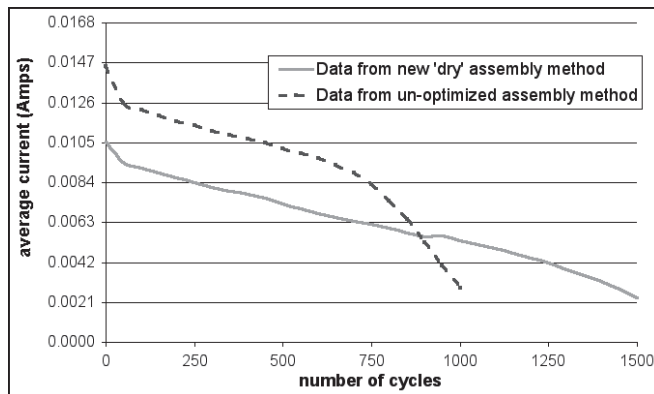


Figure 4: Plot comparison of degrading average current in assembly methods.

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