Materials Approach to Study Supercapacitor Performance

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1. Introduction

Supercapacitors are an emerging technology of large faradic capacitors. Supercapacitors operate by utilizing large surface area activated carbons in electrolyte solutions to form an electric double layer capacitor. The electric double layer capacitance is formed by the attraction of ions to the charged surface of the activated carbon. A molecular spacing between the ions in the solution and the charged surface is created by polar molecules present in electrolytes. These polar molecules line the surface of the activated carbon and act like the dielectric in a conventional capacitor. This separation of charge constitutes a capacitance and thus is called the electric double layer. Typical electric double layer capacitance per square centimeter for activated carbons can range from 6μF to 19μF [1]. The development of the electric double layer in activated carbons occurs mainly in the micropore regions with diameter smaller than 2 nm [2]. For a typical activated carbon, the surface areas can range from 100m2/g to 1500m2/g with micropore volumes of 50% or more. Thus, activated carbon materials can obtain a theoretical maximum specific capacitance of 200 F/g. In practice, the specific capacitance has a maximum of 100 F/g and is limited by the pore diameter and the pore wall conductivity.

2. Experimental Setup and Results

We have developed a new carbon material (SIU carbon) that are well suited for supercapacitor electrodes. We are in the process of preparing a patent application [3]. Experimental supercapacitors were fabricated of non activated SIU carbon, activated SIU carbon, carbon black and activated coconut carbons. Activated coconut carbons and carbon black electrodes were used for comparison purposes with the SIU carbon.

The capacitance of the supercapacitor was measured by monitoring the voltage of the supercapacitor versus time under constant current conditions. The capacitance can be calculated by multiplying the current by the inverse slope of the voltage discharge curve. Capacitance measurements were implemented in real time using a computer system with a high resolution analog to digital converter and a computer controlled constant current source. The computer system also monitored, controlled and data logged the capacitor voltage, current, time, discharge and charge state. Repeated charge and discharge cycling from 2.5 volts to .1 volt was performed to test the stability of the capacitor. Also, the self discharge characteristics were measured by charging the supercapacitor to 2.5 volts and monitoring the self discharge voltage as a function of time.

Charging and discharging experiments were conducted with the three different electrode materials at various constant current rates. The current was adjusted to maintain a reasonable charge and discharge rate and low potential drop across the internal resistance of the supercapacitor. All supercapacitance measurements were made at 22 degrees Celsius. Table 1 shows the experimental specific electrode capacitance of the various carbon materials tested. These results indicate the activated carbon nanotubes were approximately 5 times higher in specific capacitance than the activated coconut carbon materials. Also from Table 1, the specific energy density of the activated carbon nanotubes was over 109J/g. Figures 1 and 2 show the charge and discharge capacitance of the experimental activated SIU carbon supercapacitor.

3. Discussion-Conclusion

The optimum supercapacitor electrode material must have a high surface area, high conductivity, electrochemically stable surface and must develop a high double layer capacitance. Also, he electrode material must have high thermal conductivity to dissipate resistive heating and must able to bond with current collector metals such as aluminum. The recent development, SIU carbon meets most of the above criteria for a good supercapacitor electrode material. Experimental supercapacitors using this new carbon material have demonstrated specific capacities of over 90 F/g making this material a good candidate for supercapacitor application. Conventional electric double layer capacitor technologies utilize amorphous carbon materials with high specific surface area. These materials are typically made form phenolic carbon materials and carbon materials of plant origins. The conductivity of these materials is very low due to the non-graphitizability properties of the precursor materials. Non graphitized regions will not form an electric double layer that can be charged and discharged from an external source. In this work the new form of graphitic SIU carbon and its uniform dimensional size help to promote unrestricted ion diffusion to the double layer inside the material. The high conductivity of the material allows fast charging and discharging of electrons to the surface of the electric double layer. Also the absence of defects may contribute to the low leakage currents of the supercapacitor electrode due the reduction of these chemical reactions.

This new graphitic SIU carbon materials coupled to a new activation process produces a material with high conductivity and high specific surface area. Both of these properties are important for developing a high energy storage electric double layer capacitor.

Carbon type	Ct (F)	K (F/g)	E (J/g)
Act.SIU carbon	10	97	109.1
Non Act. SIU carbon	0.09	0.72	0.81
Act. Coconut	1.3	20.8	23.4
Carbon Blacks	0.27	4.3	4.86

Table 1: Specific Electrode capacitance of Various Carbons

References

[1] B. Kastening, W. Schiel, H. Henschel, J. Elecroanal. Chem., 191, 311 (1985).

[2] S. Sekido, Y. Yoshino, T. Murananka, and H. Mori, New Mat. New Processes, 1, 184 (1981).

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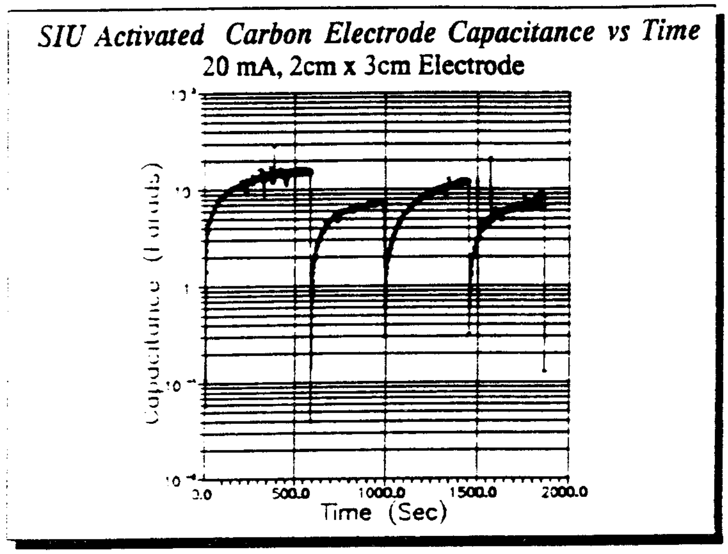

Figure 1. Capacitance vs. Time

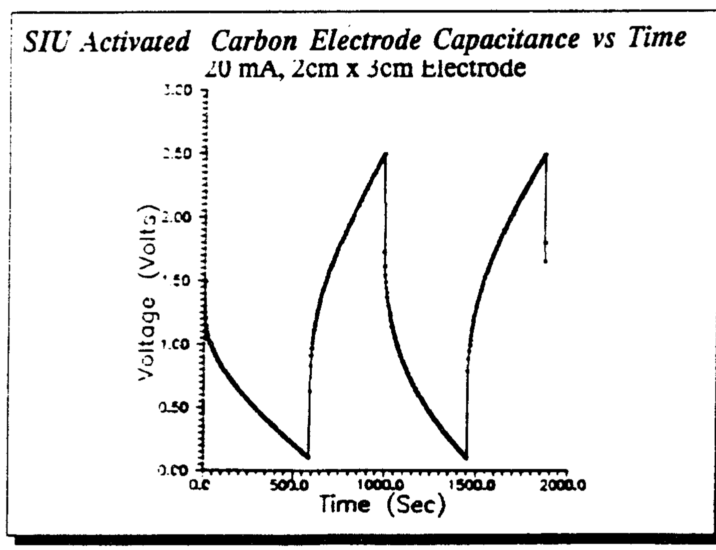

Figure 2. Voltage vs. Time