# Carbon Nanotube Based Supercapacitors

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**Introduction**

Electric energy storage has been a focus of much research for many decades and is still a rapidly expanding field to this day. The two most common forms of electrical energy storage are capacitors and batteries. Capacitors are normally known for having a high power density and a poor energy density, while batteries are known for having a high energy density and a low power density. There has been a need for an energy storage device with both high energy and power density, which is why much research has been put into super capacitors. Supercapacitors, or electric double layer capacitors, generally use a high surface area carbon based material for the electrodes. Supercapacitors also make use of an electrolyte for the purpose of transporting ions between the two electrodes[1]. Using these carbon based electrodes and electrolyte, allow the supercapacitors to maximize surface area and minimize distance between charge, which are the two main variables for optimization when dealing with capacitance.

Carbon nanotubes were vacuum filtered onto filter paper and used as the anode and cathode of the capacitor. A room temperature ionic liquid was used as the electrolyte for ion transportation within the supercapacitor. The supercapacitors were then characterized using the Solatron machines.

**Procedure**

Carbon nanotubes were mixed with 200 ml of water and three drops of triton-x. This solution was sonicated until a homogenous solution was produced. The carbon nanotube solution was then vacuum filtered onto nylon filter paper. The mat of nanotubes on top of the filter paper was cut into small circular pieces. Two of these circular pieces were placed back to back with the carbon nanotubes facing the outside. A small amount of room temperature electrolyte was placed between the two filter papers, and placed inside a coin cell apparatus that allowed one side of nanotubes to become the anode and the other side to become the cathode. This coin cell was then tested using two Solatron machines. A galvanostatic, or constant current, test was performed to calculate the direct current specific capacitance and specific energy of the coin cell. An open current test was performed to test the capacitors leakage current. Then impedance spectroscopy was used to test for the equivalent series resistance and the resistive and capacitive elements of both the carbon nanotubes and the electrolyte. This series was performed on a set of capacitors with a set of variables such as type of electrolyte, single walled or multi-walled nanotubes, and the weight of the nanotubes.

**Results and Discussion**

The variables for each of the capacitors were as follows: 1. Type of electrolyte used 2. Dry or aqueous nanotubes 3. Multiwalled or single-walled nanotubes 4. The weight of the nanotubes 5. Aluminum or no aluminum deposits on the nanotubes.

The galvanostatic test was used to observe how the capacitors voltage changes over time with a current of 1 mA charged into it. The Nyquist plot was used show the relationship between real and imaginary impedance at different frequencies of voltage. Having all unique combinations of each variable lead to over 300 different capacitors. After all the combinations of nanotubes were tested it was shown that the combination that had the greatest performance in terms of specific energy was electrolyte RTIL #7 (1-ethyl-3-methylimidazolium tetraflouroborate), Aqueous, single-walled nanotubes, with no aluminum. These parameters were used to test more cells in order to do more weight testing with the amount of nanotubes.

**Conclusion**

The tests showed that aqueous single walled nanotubes with no aluminum with RTIL #7 with a high weight showed the best performance in terms of specific energy. The individual capacitors with the dry carbon nanotubes performed better individually, but because they weighed so much more the aqueous had a better specific energy. Future work would include making many cells with these optimized qualities in order to test for reproducibility.

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**References**

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