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Carbon Nanotube Growth using Water-assisted Chemical Vapor Deposition Affected by Water Vapor Amount

Supercapacitors have the potential to further energy storage and usage. One of the methods for supercapacitors to increase capacitance is through increasing the surface area of the electrodes. Carbon Nanotubes (CNT) are able to fulfill this need, by having a high specific surface area (120-500 m²/g) and fast electron transportation. The question of how to improve CNT Creation then comes to mind. The set up for creating the CNT was through water assisted Chemical Vapor Deposition (CVD). CVD may be the best way to mass produce CNT because of its low cost to create CNT compared to the other available methods. The methods for CVD can vary, but there normally has to be three parts: the hydrocarbon, a reducing agent and an oxidizer. A hydrocarbon becomes the base for CNT at high temperatures. Reducing agents remove any oxygen from the catalyst to allow more CNT to grow. Oxidizers add oxygen to catalyst that leads to an increase in the time that the reaction can occur. The ratio between all these gases was altered in these tests. The ratios of H₂: C₂H₄: H₂O went from 1:2:5 to 1:2:2.

Carbon Fiber Substrates were initially sputtered with Alumina and then the catalyst; iron. The substrate was then placed into the furnace and tightly sealed. The substrate, before CVD, is weighed to compare with the substrate after CVD. First the system needs to flush out all the oxygen, which was done using an Argon Hydrogen mix (95% Argon/5% Hydrogen) at 500 sccm. Afterwards, the furnace was heated to 800 Celsius and the substrate adjusts to the temperature for 15 minutes. Then the Hydrocarbon, Ethylene (C₂H₄), flowed through the system at 20 sccm for around two hours. The Argon Hydrogen mix was decreased during this time to around 210 sccm, for the hydrogen to be close to 10 sccm. The hydrogen is acting as a reducer in the reaction. Three minutes after the Hydrocarbon was released, the flow of the argon hydrogen mix also flowed through a regulated bubbler, of either 50 sccm or 20 sccm, to act as an oxidizer. Three minutes before the ethylene had been flowing for two hours, the bubbler was stopped and sealed. After the two hours, the flow of Ethylene was stopped and sealed. Afterwards the Argon Hydrogen mix was set back to 500 sccm, to flush out any remaining gases, as the furnace was shut down and cooled to room temperature.

When the samples are removed, the weight must be taken again to assist in quantifying the amount of CNT that have formed. The metals are then removed from the substrate, as to not interfere with the capacitance, using an acidic solution. The substrate, after drying, has one square centimeter of the CNT placed opposite to a platinum plate a set distance to form the electrodes for a capacitor. The electrode is then submerged into an electrolyte (sodium sulfate solution) to test each CNT sample to its optimal capacitance value. The CNT's are tested using Cyclic Voltammetry and Charge Discharge. The Charge Discharge is based off of Amperes per gram, so each sample will have a different current. The reasoning behind the variance between each sample is to see how long it takes the sample to reach a given potential with each of the ratios. The variation

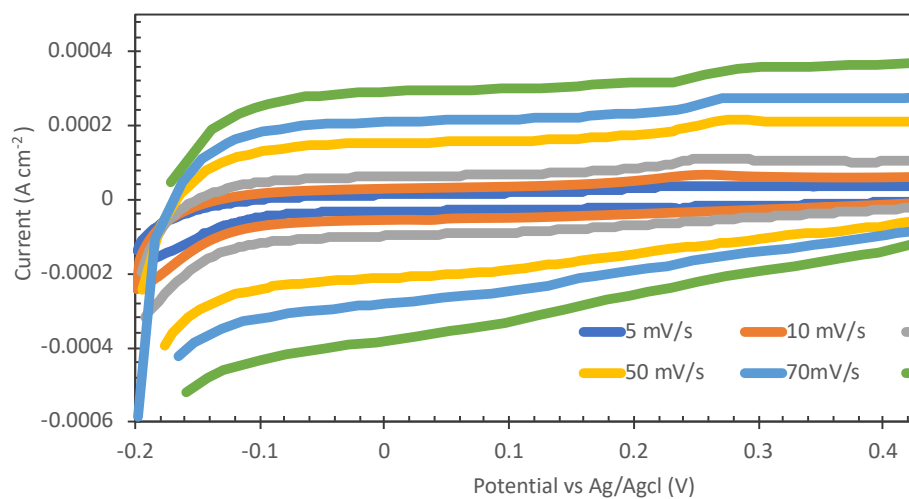
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between each sample is calculated by dividing the mass of the CNT by the area of the substrate. This ratio is directly related to the needed Amps because only one square centimeter is placed in the electrolyte. Capacitance is then calculated using the area under the Cyclic Voltammetry curve. The closer to ideal curves the electrodes, the more capacitance in the sample. The ideal curve for Cyclic Voltammetry is a rectangle, while Charge Discharge is a triangle. Though both rations lead to very ideal curves for both tests, Test B had a much larger CV curve compared to Test A.

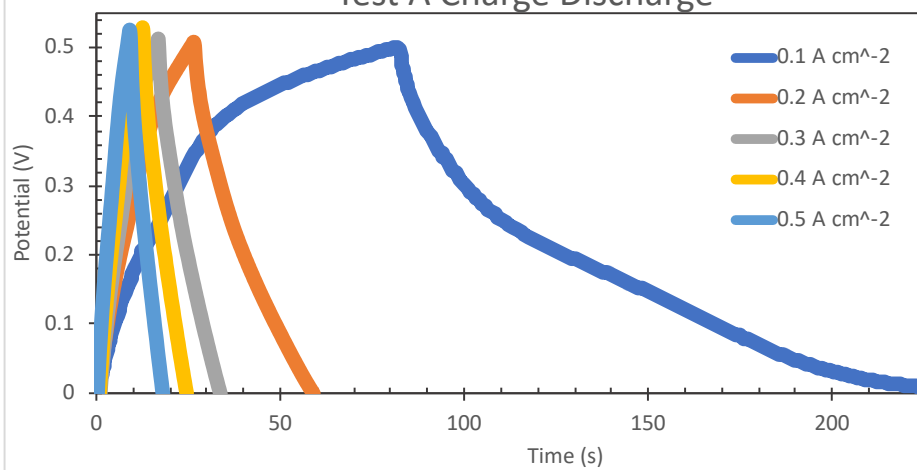
The two methods of CVD used varied only on the amount of water vapor flowing through the system. Test A used 50 sccm and Test B used 20 sccm. Through the calculations it was found that Test A had 9.33 F/g and Test B had 24.41 F/g. The cause of the great discrepancy between the tests could be caused because the water vapor acts as an oxidizer in CVD. Too much oxidation and the iron catalyst will not absorb the carbon and over saturate to form CNT. Less CNT grown means less surface area on the electrode, leading to less capacitance. Though too little water causes more amorphous carbon to form during CVD, also affecting capacity. In order for supercapacitors to increase their capacitance to be competitive with batteries, the surface area of the electrodes must increase.

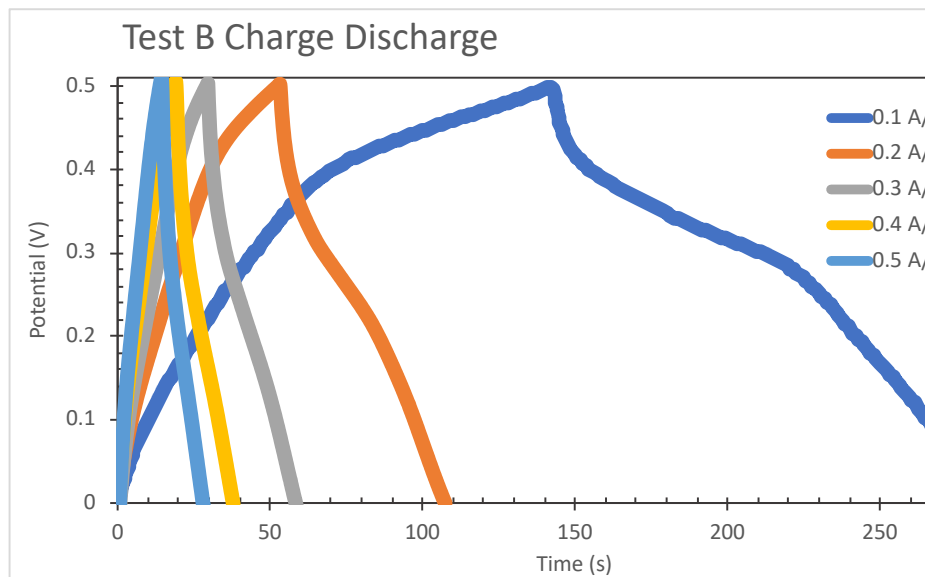
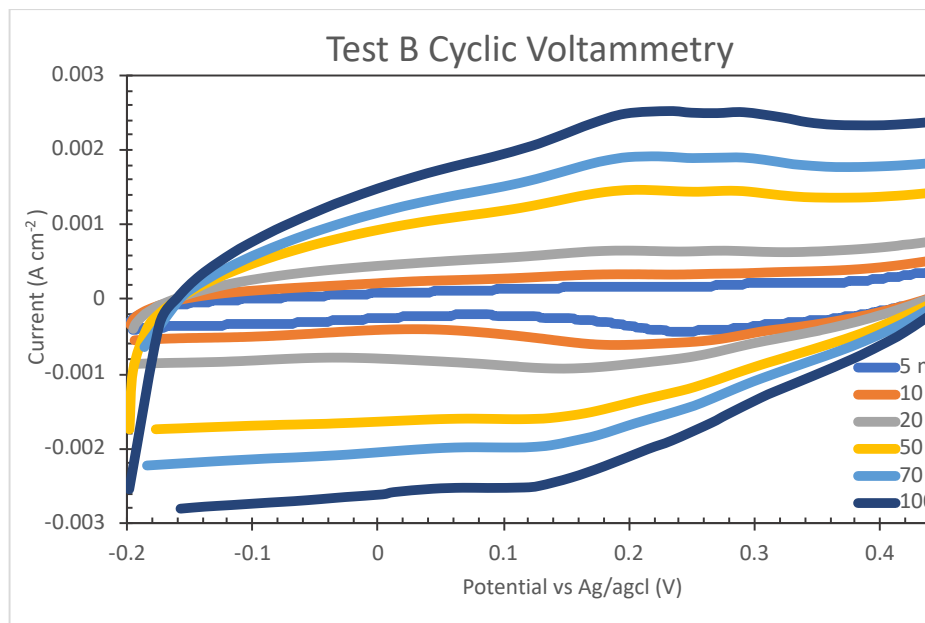
Graphs:

Test A Cyclic Voltammetry

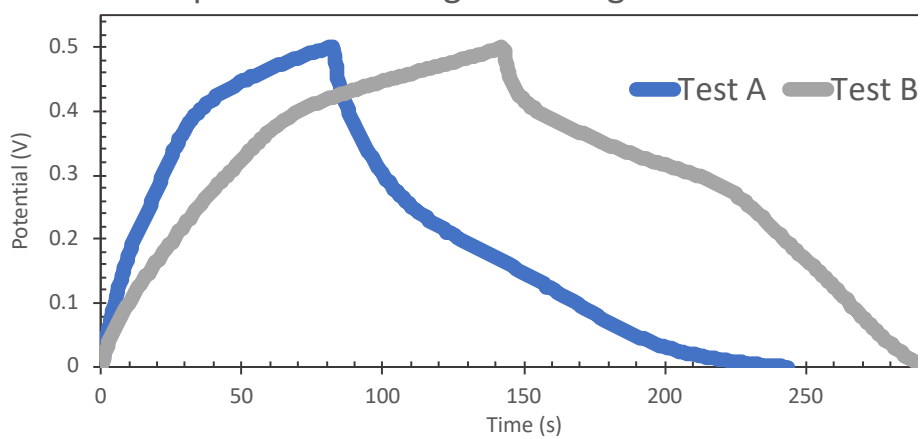


Test A Charge Discharge





Comparison on Charge Discharge at 0.1 A cm^{-2}



Comparison on Cyclic Voltammetry at 20 mV s^{-1}

