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Preparation of Carbon Powder and Carbon Powder-CNT Mixture for Supercapacitor Application

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***Abstract*—Supercapacitor offers high energy density, stability and can be build using environment-friendly material. To deepen understanding on how supercapacitor material effect its properties, this work study the effect of treatment on every component of supercapacitor. The capacitor is composed by electrodes, current collector, separator and aqueous electrolyte. The electrode made from activated carbon (AC) and mixture of activated carbon with carbon nanotube (CNT). Before applying to current collector AC and CNT is heat treated in 800°C for an hour for AC and 650°C for 30 minutes for CNT. The current collector treated with cleaning, sanding and applying conductive paint. After treatment has given, capacitor then assembled and 6M KOH of electrolyte added. Supercapacitor then analyzed and characterized using constant current discharge (CCD) technique. The characterization result showed that there is decrement in supercapacitor internal resistance and heat treatment on electrode material improves capacitance of supercapacitor when compared to the untreated one.**

Keywords*—carbon powder and carbon powder-CNT (carbon nanotube), high energy density and stability, and environment-friendly material

I. Introduction

Compared to conventional capacitor, electrochemical supercapacitor has higher energy density, higher stability, faster charge-discharge and longer lifetime. Electrochemical supercapacitor, often called ultracapacitor or just supercapacitor, also can be manufactured using less cost, widely available and environment friendly materials. The supercapacitor comprises of a pair of electrodes on top of current collector, electrolyte and a separator. Different material or treatment in each component may result to different electrochemical performance of supercapacitor such as capacitance or internal resistance. Treatment such as re-heat electrode material may improve supercapacitor capacitance [1-3]. Supercapacitor stored energy by capturing positive and negative ion of electrolyte in the electrode when each electrode polarized.

Based on electrode material, supercapacitor can be classified into three categories. They are Electrochemically Double-layer Capacitors (EDLC), Pseudocapacitors and Hybrid Capacitor. EDLC attracts many researchers since its electrode is made from carbonaceous material that have high electrically conductivity, large theoretical surface area, low cost and environmental friendly. Activated carbon (AC) [1-3], carbon nanotubes (CNT) [4-6], carbon nano fibers [7] or mixture of AC-CNT [8] can be used as electrode in EDLC. Supercapacitor already applicable in automotive Industry [4], power electronics and consumer electronics [7].

This research focused on studying the effect of different treatment that applied on electrode's material and current collector. The electrode material is made from activated carbon and carbon nanotube. Current collector is made from aluminium plate. Effect on different treatment on capacitance compared between treated and non-treated material.

II. Experiment

A. Preparation Method

Current collector, 2.5cm x 4 cm in size and made from aluminium, is treated with cleaning using acetone, sanding with 150 sandpaper and conductive paint is then applied. For electrode, activated carbon is heated at 800°C for 1 hour in inert atmosphere and carbon nanotube is heated at 650°C for 30 minutes. Table 1 shows composition of supercapacitor samples that are made from treated material and non-treated material. Treated material is expected to have better capacitance or internal resistance than untreated material.

TABLE I. Samples Made from Treated and Non-Treated Material

Sample	Treated AC	Non-treated AC	CNT	Treated Current Collector	Non-treated current collector	Binder	Ratio
1	-	V	-	V	-	5%	95:5
2	-	V	-	-	V	5%	95:5
3	V	-	-	V	-	5%	95:5
4	V	-	V	V	-	5%	90:5:5

Binder used for supercapacitor shown in table 1 is PVA. This binder is used not only to maintain electrode structural integrity, but also to ensure electrode material firmly adhere to current collector. Supercapacitor sample is made by mixing electrode material and binder to make electrode paste. This paste is then applied to a pair of current collector and then each current collector sandwiched with a separator and electrolyte in between current collector as shown in figure 1. Electrolyte used for all sample is 6M KOH. KOH is selected as electrolyte because of its high ionic conductivity [] and separator using a polypropylene membrane with 0.8mm thickness. Polypropylene membrane is used because it has good electrical insulation and have high electrical and electrochemical stability in electrolyte.

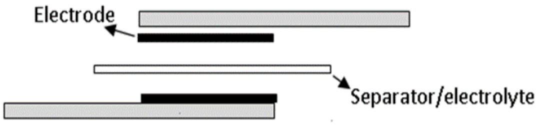

Fig. 1. Supercapacitor sample structure.

B. Electrical Test Method

The produced capacitor is analyzed using Charge and Discharge Method. There are two states during the test, charging and discharging state. Figure 2 shows the setup of the test. Supercapacitor sample under test is first charged by connecting the capacitor to a 0.6 V voltage source. After reached 0.6 V, the supercapacitor sample is discharged by connecting it to a resistor load. During charging and discharging state current and voltage of supercapacitor is measured and recorded. This test is used to determine the effect of treatment on current collector and only applied to compare current flow toward sample 1 and sample 2 during charging state.

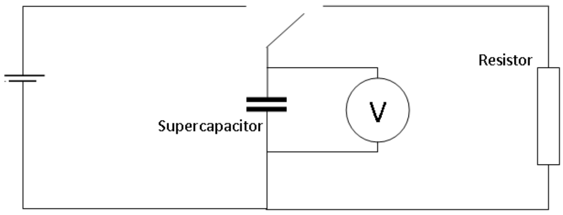

Fig. 2. Supercapacitor test circuit.

For sample 1, 3 and 4, the test circuit is modified. Load resistor is replaced by constant current sink. Current out from supercapacitor is maintained at 10 mA. Once current fell below 10 mA during discharging or sample voltage reach 0,6V for 5 minutes during charging, the switch is switched to another state. For example, during charging state, once the capacitor voltage reached 0.6V for 5 minutes, the switch will switch to discharge state. This test often called constant current discharge test. This test is performed due to capacitance of supercapacitor cannot be determined accurately using LCR or an in-circuit tester [9]. Figure 3 shows typical result of constant current discharge test on a supercapacitor sample. From this test, we can find out capacitance and internal resistance of a supercapacitor. Capacitance can be calculated using following formula:

$$C = \frac{I\,x\,(T_2 - T_1)}{(V_1 - V_2)} \tag{1}$$

Where C is capacitance in farad (F), I is current flow during discharge state in ampere (A), V_1 and V_2 are recorded voltage (V), T_1 and T_2 are time from start discharge state to T_1 and T_2 in second (s). ΔV indicate voltage drop during discharging state. This voltage drop is caused by internal resistance that reduced energy stored in supercapacitor [10]. Higher internal resistance means more deeper voltage drop.

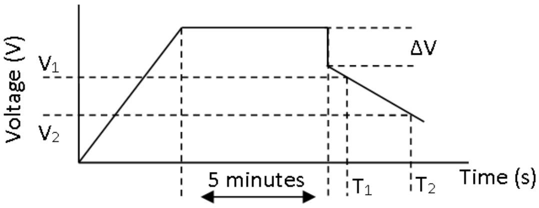

Fig. 3. Typical result of constant current discharge test.

III. Results and Discussion

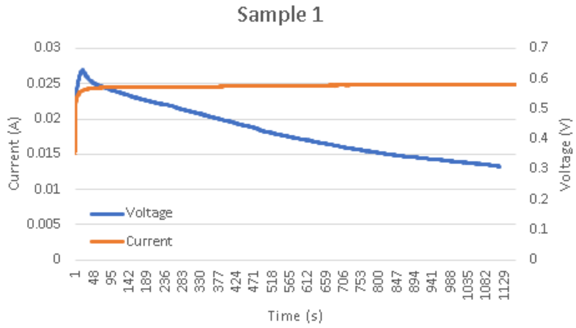

Fig. 4. Charging test result on sample 1.

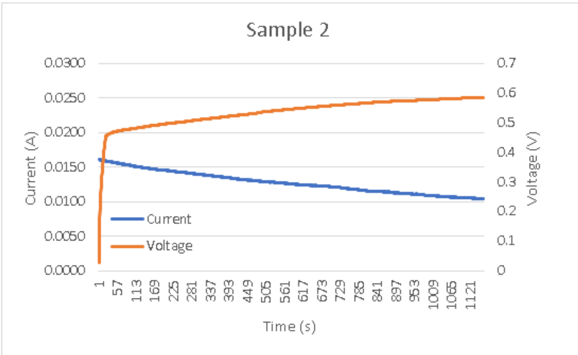

Fig. 5. Charging test result on sample 2.

Figure 4 and figure 5 show test result on sample 1 and sample 2. The two sample is prepared to study the characteristics of non-treated current collector. This result is taken during charging state. Figure 4 shows that the current flow toward supercapacitor sample can reach more than 25 mA. When the voltage of supercapacitor sample reach 0.54V, current flow starts to gradually reduce. Figure 5 shows that the current toward supercapacitor sample 2 reach about 15 mA. When the voltage reaches 0.5V, the current starts to decrease while voltage slowly increase to reach intended voltage 0.6V. From both tests, it can be determined that current flows in sample 1 is higher than sample 2 due to lower contact resistance between electrode and current collector. Once the voltage reaches certain value (0.5V), the current flows toward supercapacitor begin to decrease due to decreasing potential difference between voltage source and supercapacitor.

The following test is to determine capacitance value from sample 1, sample 3 and sample 4. The difference of each sample, can be seen in table 1. Sample 1 electrode is made only with non-treated activated carbon. Sample 3 electrode is made from treated activated carbon and in sample 4 electrode is made from a mixture of treated activated carbon and carbon nanotube. This test carried out by charging supercapacitor to reach 0.6V and maintain capacitor voltage for 5 minutes. After 5 minutes, supercapacitor sample discharged with constant current load. Discharging current maintained at 10 mA. Figure 6 shows test result for sample 1. From figure 6 can be determined that there is about 0.2 V voltage drop in the beginning of discharging state. The voltage of supercapacitor gradually decreasing after voltage drop. Using equation from previous section, it can be determined that the capacitance of sample 1 is 4 F or about 14.28 F/g.

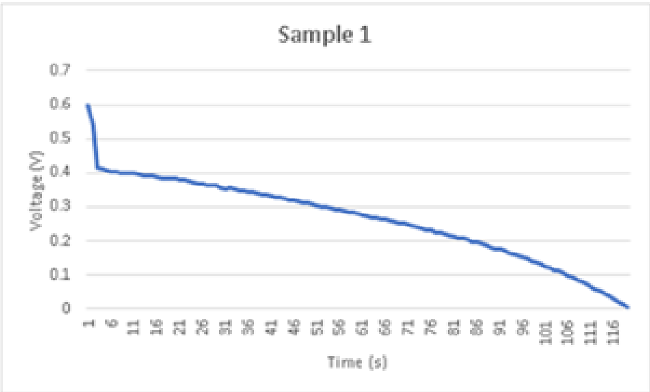

Fig. 6. Constant current discharge result on sample 1.

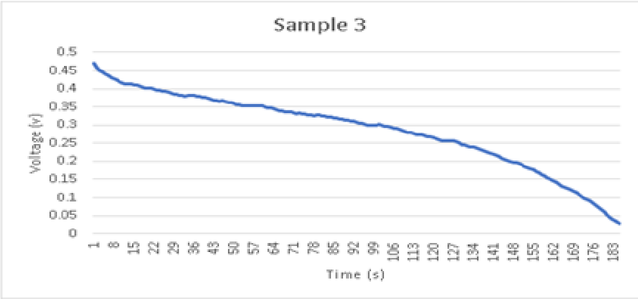

Fig. 7. Constant current discharge result on sample 3.

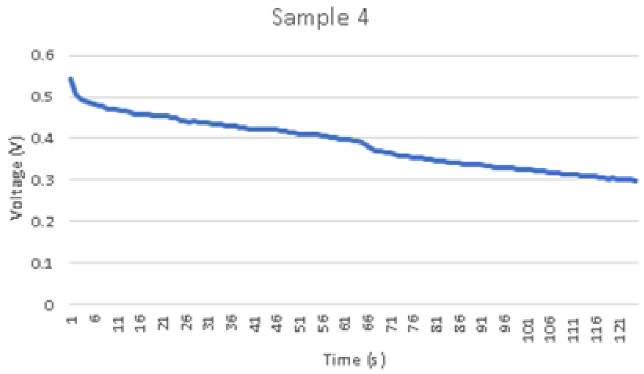

Fig. 8. Constant current discharge result on sample 4.

Figure 7 shows test result of supercapacitor sample 3. From this result, we can determine that there is voltage drop about 0.18V from 0.6V to 0.42V. After voltage drop, sample voltage reduces gradually during discharging. The capacitance of supercapacitor sample 3 is 6.625 F or about 27.6 F/g. Figure 8 shows that voltage drop in the beginning of discharge state is lower than sample 1 and sample 3. It indicates about 0.1 V voltage drop and capacitance is 5.75 F or about 23.95 F/g. Supercapacitor sample 4 shows lowest voltage drop compare to sample 1 and sample 3. This result may be caused by carbon nanotube (CNT) addition into sample 4's electrode material. Addition of CNT not only reduce voltage drop of sample 4, but also reduce capacitance of sample 4 compare to sample 3. Sample 1's capacitance is the lowest compared to sample 3 and sample 4. This low capacitance may be caused by activated carbon that used into sample 1's electrode is not receiving heat treatment. Sample 1 also has deepest voltage drop in the beginning of discharging state, this drop indicates that supercapacitor sample 1 have highest internal resistance compared to supercapacitor sample 3 and supercapacitor sample 4. The increase on capacitance in sample 3 compare to sample 1 is because heat treatment on activated carbon can increase electrode's conductivity. This increase may come from the modified surface of activated carbon due to heat treatment adsorbs electrolyte ion more easily [1]. More electrolyte ion adsorbed, more capacitance the supercapacitor sample have. Reducing internal resistance on sample 4 compare to other samples may cause by CNT addition that have higher conductivity rather than activated carbon.

IV. Conclusion

Based on test result showed that treatment on current collector may increase current toward supercapacitor during charging state. Capacitance value of supercapacitor sample 1 is 14.28 F/g. This result is the lowest among all sample that can reach 27.6 F/g for supercapacitor sample 3 and 23.95 F/g for supercapacitor sample 4. This indicates that heat treatment given to activated carbon that makes up sample 3 and sample 4 electrode can increase capacitance value of supercapacitor. Carbon nanotube (CNT) addition may reduce internal resistance of supercapacitor. CNT addition also reduces capacitance value of supercapacitor.

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