Manufacture and Measurement of Graphene-based Supercapasitor Electrodes and Characterization using Charging-discharging Method

Ivan Anggia Sihotang, Kerista Tarigan and Syahrul Humaidi
Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Sumatera Utara, Medan, Indonesia

Keywords: Graphene, Activated Carbon, Epoxy Resin, Phosphoric Acid (H_3PO_4), Aluminum Plate, Supercapacitor.

Abstract: Supercapacitors or known as EDLCs (Electrochemically double-layer Capacitors) are electric double layers separated by separators. Supercapacitors provide very high power density values, long repetition cycles and have a higher repetition efficiency compared to batteries. This study aims to design a supercapacitor with a material of 0.905 gram graphene powder, 2 gram activated carbon, epoxy resin (3 spoonfuls of spatula), Phosphoric Acid (H_3PO_4) electrolyte solution, and aluminum plate with a size of 8 cm x 8 cm, 6 cm x 6 cm, and 5 cm x 5 cm as collector media. The research was carried out in four stages, namely mixing graphene powder and epoxy resin, coating graphene-epoxy resin powder on both plates, sowing activated carbon on the surface of the plate, and combining the two plates into one supercapacitor section. The test results show that with the charging-discharging method, the size of 8 cm x 8 cm which is carried out charging for 3 minutes can store a voltage of 1.65 Volt, on the size of 6 cm x 6 cm done charging for 3 minutes can store a voltage of 1.44 Volt, and at a size of 5 cm x 5 cm by charging for 3 minutes can store a voltage of 1.05 Volt. So it can be proven that the cross-sectional area of a supercapacitor greatly influences the value of the stored voltage.

1 INTRODUCTION

The development of advancements in technology now makes everyone need electronic devices that are able to support their work to make it easier and more practical. Therefore these electronic devices must have a great ability to store energy. Large energy storage is needed so that these electronic devices are able to work optimally and are durable in order to support the work to be more practical and efficient. One of the energy storage that is commonly used is the battery, the battery is used because it is more practical and only disposable, but this is also a disadvantage because it cannot last long in use, has no economic value, produces waste that is harmful to the environment, and the power is also stored tend to be small. That is why lately people have begun to turn to supercapacitors.

Supercapacitors or known as EDLCs (Electrochemically double-layer Capacitors) are electric double layers separated by separators. Supercapacitors provide very high power density values, long repetition cycles and have a higher repetition efficiency compared to batteries. From a technical point of view, supercapacitors have a relatively large number of cycles (> 100000 cycles), high energy density, large energy saving capacity, simple principles and easy construction (Hyeok, 2001). Whereas in terms of user friendliness, supercapacitors increase safety because there are no corrosive materials and less toxic materials.

Supercapacitors collect the charge from the absorption of electrostatic ions onto the surface of the double layer electrode / electrolyte to the conduction material at a specific surface area in this case, activated carbon. The electrodes commonly used are carbon and also metal plates. But what is often used lately is carbon because metal plates have no economic value and their ability as an electrode to store a charge is relatively small. Therefore carbon is more often used as an electrode in supercapacitors. To increase the specific surface area, carbon is activated so that its ability to increase the charge is better.

Among carbon materials, graphene is the most promising material as an electrode for energy storage device applications because it has a high surface area, is relatively inexpensive, has high electrical conductivity. This material has an electron mobility of 15,000 $cm^2/V \cdot s$, a thermal conductivity of 5,000

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$Wm^{-1}K^{-1}$. Graphene is an ideal material for fabricating supercapacitors because it has a large surface area of 2630 m^2/g and intrinsic electrochemical capacitance of ~ 21 mF/cm^2. This value is the maximum value for all carbon-based materials (K & Carlen, 2000).

In this research, graphene-based supercapacitor electrodes will be made, where graphene functions as carbon material used in the process of making supercapacitor electrodes.

2 MATERIALS AND METHODS

2.1 Material Used in Research

The materials used in this study are graphene powder, activated carbon, epoxy resin, phosphoric acid (H_3PO_4) electrolyte solution, aluminum plate, and separator (tissue).

Graphene functions as a cathode electrode and a double layer super capacitor anode that will receive electrical energy from the collector and then store the electric charge while after that the electrical charge is wasted. In this study graphene powder used was 0.905 grams for each supercapacitor.

Activated carbon is used as an anode and cathode just like graphene powder, and activated carbon powder also functions as a store of electric charge and a second layer after graphene to be given an electrolyte solution. In this study active carbon powder was used for 2 grams for each supercapacitor.

Epoxy resins are used as an adhesive between graphene powder, activated carbon and laminating foil. in addition, epoxy resin also serves as a protector so that the electrolyte liquid cannot touch the collector laminating foil and also so that there is no loss of capacitance that will make electrons move to the collector. In this study epoxy resins used 3 spoonfuls of spatula for each supercapacitor.

Phosphoric Acid (H_3PO_4) electrolyte solution functions as an electrolyte in the supercapacitor to be dripped into a separator (tissue), where positive and negative ions will react. Positive and negative ions will move freely when before being given a voltage and when given a positive and negative ion will be attracted to the electrode.

This separator (tissue) functions as a separator between anode and cathode mixed with an electrolyte solution and also as a polarity bridge.

The aluminum plate is used as a collector between the anode and the cathode, which is a double layer or the right and left side of the supercapacitor that will receive electrical energy and then be delivered to the electrodes. The aluminum plate used has a thickness of 0.2 mm with a size of 8 cm x 8 cm, 6 cm x 6 cm and 5 cm x 5 cm. The surface of the aluminum plate must be clean so that the graphene powder and activated carbon can be attached to the surface of the aluminum plate.

2.2 Overall Research Procedure

This research procedure has several stages. First, the aluminum plate is divided into two equal parts, each measuring 8 cm x 8 cm, 6 cm x 6 cm and 5 cm x 5 cm. Then graphene is mixed with epoxy resin powder with a ratio of 0.905 grams of graphene powder and 3 tablespoons spatula epoxy resin, after that it is stirred until evenly distributed. The results of the mixture of graphene and epoxy resin were immediately applied to both parts of the aluminum plate, each of which had a specified size. Let stand the results for 5 minutes, then sprinkle the activated carbon powder on top of the aluminum plate evenly, so that the activated carbon is attached to the aluminum plate.

Second, unite the two parts of the aluminum plate by placing a tissue between the two parts of the aluminum plate while dripping with a solution of Phosphoric Acid (H_3PO_4) electrolytes to the tissue in an adequate ratio. Then press and clamped both sides of the aluminum plate that was joined together so that it sticks. Make a current collector on each part of the electrode using a crocodile cable / clamp. After that measured the voltage (V) stored and the length of time with the charging-discharging method.

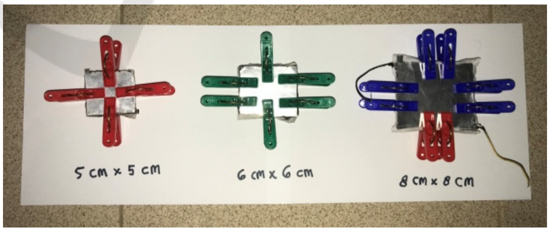

Figure 1: Three supercapacitors designed.

Double-layer electric capacitors or EDLCs are based on the working principle of the dual electric layers that form on the inter-surface layer between activated carbon and electrolytes as dielectric. The mechanism of absorption and desorption of ions on both layers of activated carbon electrodes plays a role in EDLCs charging and emptying. By applying voltage to the facing electrodes the ions will be attracted to the surface of the two electrodes and the charging process will occur. Instead, ions will move away when EDLCs is used or discharging (Murata America Co. Ltd., 2011). The charging and discharging process of EDLCs can be seen in Figure 2.

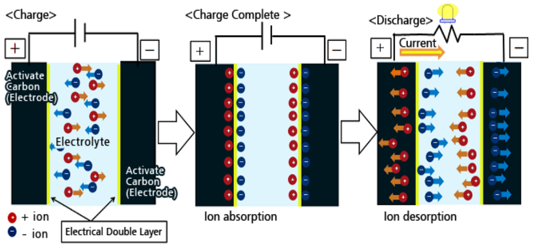

Figure 2: Scheme of charging and discharging process on EDLCs (Murata co, Ltd, 2011).

3 RESULT AND DISCUSION

3.1 Charging-discharging Method

The results of the research making supercapacitors by varying the cross-sectional area with a size of 8 cm x 8 cm, 6 cm x 6 cm, and 5 cm x 5 cm. Where in this test using the charging-discharging method, charging for 3 minutes with an input voltage (V) of 3 Volt.

3.1.1 Testing on a Supercapacitor with Size of 8 Cm x 8 Cm

With the charging-discharging method, a storage voltage of 1.65 Volt is obtained. And the time of discharge can be seen in the table below.

Table 1: Discharge Time.

Time (sec)	Voltage (V)
0	1.65
5	1.61
10	1.58
15	1.55
20	1.53
25	1.52
30	1.50
35	1.48
40	1.47
45	1.45
50	1.44
55	1.43
60	1.42
65	1.41
70	1.40
75	1.38

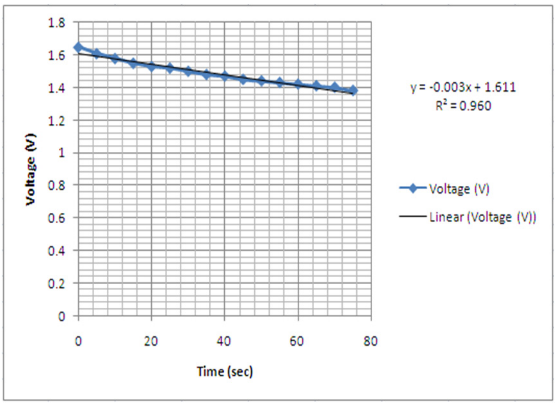

Figure 3: Graph of discharge voltage vs time.

3.1.2 Testing on Supercapacitor with a Size of 6 Cm x 6 Cm

With the charging-discharging method, a storage voltage of 1.44 Volt is obtained. And the time of discharge can be seen in the table below.

Table 2: Discharge Time.

Time (sec)	Voltage (V)
0	1.44
5	1.42
10	1.41
15	1.39
20	1.37
25	1.36
30	1.34
35	1.33
40	1.32
45	1.31
50	1.29
55	1.28
60	1.27
65	1.26
70	1.25
75	1.24

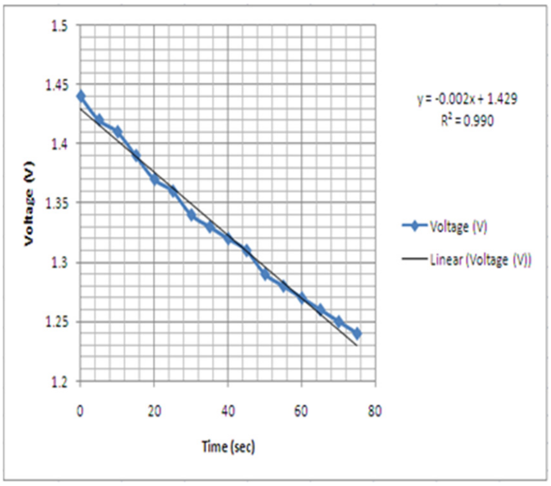

Figure 4: Graph of discharge voltage vs time.

3.1.3 Testing on Supercapacitors with a Size of 5 Cm X 5 Cm

With the charging-discharging method, a storage voltage of 1.05 Volt is obtained. And the time of discharge can be seen in the table below.

Table 3: Discharge Time.

Time (s)	Voltage (V)
0	1.05
5	1.04
10	1.03
15	1.02
20	1.02
25	1.01
30	1.00
35	0.99
40	0.98
45	0.97
50	0.97
55	0.96
60	0.95
65	0.94
70	0.93
75	0.92

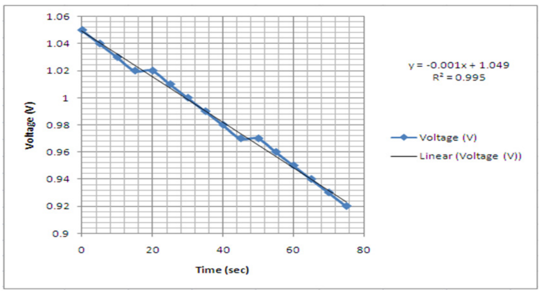

Figure 5: Graph of discharge voltage vs time.

3.2 Capacitance Testing of Supercapacitor

This test is carried out to find out what is the value of capacitance in each supercapacitor. Where the plate cross-sectional area is known, the distance between the two plates and the dielectric constant value of the material. By using the equation below.

$$C = \varepsilon_o \varepsilon_r \frac{A}{d} \qquad (3.1)$$

3.2.1 Capacitance Testing of Supercapacitors with a Size of 8 cm x 8 cm

Determine the cross-sectional area of the supercapsitor using the equation below.

$$A = s \times s \qquad (3.2)$$

Then obtained:

A = 8 cm x 8 cm
$A = 64\ cm^2$

Next determine the capacitance value using equation 3.1. where for the similar ε_r separator value which is a polymer material is assumed to be 10,000 through previous research. So we get the results:

$$C = \varepsilon_o \varepsilon_r \frac{A}{d}$$

$$C = (8.854\ x\ 10^{-12}\ F.m^{-1})\ x\ 10000\ x\ \frac{64\ cm^2}{1\ mm}$$

$$C = 0{,}57\ x\ 10^{-6}\ F$$

3.2.2 Capacitance Testing on Supercapacitors with Size 6 cm x 6 cm

Determining the cross-sectional area of the supercapsitor by using equation 3.2 we get:

A = s x s
A = 6 cm x 6 cm
$A = 36\ cm^2$

Next determine the capacitance value using equation 3.1 so that the results are obtained:

$$C = \varepsilon_o \varepsilon_r \frac{A}{d}$$

$$C = (8.854\ x\ 10^{-12}\ F.m^{-1})\ x\ 10000\ x\ \frac{36\ cm^2}{1\ mm}$$

$$C = 0{,}319\ x\ 10^{-6}\ F$$

3.2.3 Capacitance Testing on Supercapacitors with a Size of 5 Cm X 5 Cm

Determining the cross-sectional area of the supercapsitor by using equation 3.2 we get:

A = s x s
A = 5 cm x 5 cm
A = 25 cm^2

Next determine the capacitance value using equation 3.1 so that the results are obtained:

$$C = \varepsilon_o \, \varepsilon_r \, \frac{A}{d}$$

$$C = (8.854 \; x \; 10^{-12} \; F.m^{-1}) \; x \; 10000 \; x \; \frac{25 \; cm^2}{1 \; mm}$$

$$C = 0{,}221 \; x \; 10^{-6} \; F$$

4 CONCLUSIONS

Manufacture and Measurement of Graphene-Based Supercapasitor Electrodes and Characterization Using Charging-Discharging Method have been done. The results show that with the charging-discharging method, a supercapacitor with a size of 8 cm x 8 cm, 6 cm x 6 cm, and 5 cm x 5 cm after charging for 3 minutes with a 3 volt input voltage will obtain the stored voltage in a row of 1.65 volts, 1.44 volts, and 1.05 volts. And by varying the cross-sectional area of the supercapacitor, the capacitance value can also be determined using a predetermined equation. So that it can be proven that the cross-sectional area of a supercapacitor greatly affects the value of capacitance and the amount of voltage stored.

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