Study and Analysis of Shape of Electrode Implemented in Supercapacitor with Focus on Design and Fabrication for Application in Load

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ABSTRACT

Electric energy storage is an essential issue in the modern world. Various sorts of research on batteries and supercapacitors are now underway. Supercapacitor is an alternate energy storage device with a high power density and specific capacitance. A supercapacitor is a device that stores electric energy as an electrostatic field. We show a model of an asymmetric supercapacitor built using an anode of activated carbon + manganese dioxide coating on a stainless-steel gauge and a cathode of pure activated carbon coating. Also incorporated with the polyethylene separator. The supercapacitor's energy storage is controlled through modifying the spacing across the two electrodes and the physical shape of the electrodes. We tried four different electrode shapes: square, rectangle, triangle, and semicircle. It has been observed that modifying the shape of the electrode had an effect on most of the parameters. This can be achieved by experimenting with the actual configuration by changing the shape of electrodes in a supercapacitor. This provides excellent results and graphs displaying the maximum capacitance of supercapacitor with rectangular electrode designs.

Keywords— Super Capacitor, Symmetrical Super Capacitor, Asymmetrical Super Capacitors, Activated Carbon, Hybrid Super Capacitor, Ultra Capacitor, Shape of Supercapacitor, Electrode Shape, Different Materials of Supercapacitor

I. INTRODUCTION

Supercapacitors are divided into three types depending on their electrode configuration: symmetric supercapacitors, asymmetric supercapacitors, and battery-type supercapacitors. Symmetric supercapacitors have a pair of electrodes with identical behavior on both sides of them. Supercapacitors (which are additionally referred to as Ultracapacitors) electrochemically store charge.

Supercapacitors are categorized into two categories based on charge storage: Electrochemical double layer capacitors (ELDCs) and Pseudocapacitors. Electrochemical Double Layer Capacitors (ELDCs) are charge storage devices with a high energy density. Carbon nanomaterials such as carbon nanotubes and graphene are used as electrodes in Electrochemical Double Layer Capacitors (ELDCs). Pseudocapacitors store energy by charge transfer between electrode and electrolyte [1].

The most prevalent kind of supercapacitor is the symmetric capacitor. Asymmetric supercapacitor design is simpler than symmetric supercapacitor design. Symmetric supercapacitors in aqueous electrolytes may achieve a high cell voltage while also improving energy density.

Manganese (Mn)-based materials are the most researched electrode materials based on metal oxides. Increasing the working potential of Mn_3O_4 enhances the energy of supercapacitors in aqueous electrolytes [2].

Electrochemical energy storage devices commonly referred as Flexible Symmetric Supercapacitors (FSS). The high density, expanded cycle life, and flexibility of Flexible Symmetric Supercapacitors (FSS) are well recognized. The layer of one solid electrode is coated by two electrode layers in Flexible Symmetric Supercapacitors (FSS).

The development of nanomaterials is critical for improving the performance of Flexible Symmetric Supercapacitors (FSS). The needed solid electrolytes must be mechanically bendable [3].

Supercapacitor technology is advancing in order to deliver enhanced energy storage application platforms. Fabrication of supercapacitors is critical for speedy charging as well as improving qualitative performance.

Electrodes are typically made of metal oxides. Metal oxides are highly conductive. Concentrated MnO_2 and MnO_2 doped V_2O_5 with high capacitance density have been explored. The metal oxides explored for electrodes are both cost effective and environmentally favorable [4].

The asymmetrical supercapacitors operational voltage is maximized by employing two distinct materials on the electrodes. Graphene oxides are used to create asymmetric supercapacitors with high energy density. MnO_2 is placed on the positive electrode, while RGO is applied to the negative electrode before being immersed in Na_2SO_4 electrolyte. Asymmetric capacitor technology makes use of both the no faradic charge storage demonstrated by carbon materials and the nonfaradic charge storage demonstrated by pseudocapacitance. This capacitor architecture boosts capacitance and energy density while allowing for a high cycle life, combining the benefits of both electrostatic and faradic storage [5] [6].

Energy storage systems are in great demand due to the introduction of new electric vehicles that employ battery systems that require extended charging times of up to 7-8 hours and are expensive. The supercapacitor is utilised as an alternate method of energy storage since it charges quickly and provides a high supply of energy. A capacitor is a tool that stores energy in an electrostatic field and is utilised as needed. The supercapacitor is a double-layered, more energy-dense variant of the capacitor that was invented more recently. The area and capacitance both increase as a result of the second layer. Supercapacitors may be applied in a variety of forms and sizes and are more adaptable and simple to use than batteries [7][8][9].

Solid-state, thin, flexible, secure, and economically viable energy storage devices that can be easily integrated with printable and wearable electronics are imperative due to the rapid growth of these innovations in technology. These applications are particularly suited for solid supercapacitors (also known as electrochemical double layer capacitors, or EDLC), whose main components, solid polymer electrolytes and carbon electrodes, can both be produced entirely of ecologically friendly and sustainable materials. An affordable raw material for biomass (wood, agricultural waste, etc.) has been ignited to produce biochar activated carbons (AC), which are then further adjusted or modified by chemical activation. EDLC electrode materials showing potential. The primary characteristics of biochar AC for various energy storage applications are its extremely high surface area, micro- and meso-pore structures, and surface chemistries [10].

The need for more energy globally is driving the development of unconventional or alternative energy sources with high power and energy densities. Typical non-conventional energy sources based on the principle of chemical-to-electrical energy conversion include batteries, fuel cells, and supercapacitors. They have numerous uses in consumer electronics, including hybrid cars, digital cameras, emergency doors, and mobile phones. Electrochemical processes are used in these devices to transform chemical energy into electrical energy. As far as the fuel cells are concerned, electrical energy can be produced as long as the fuel is fed. With batteries, the energy that has been stored can be used when it is needed [11].

Concerns regarding climate change, the negative effects of petroleum dependence for many nations, and an increasingly interconnected world require significant improvements. Electrical energy storage systems (ESS) have grown to be a significant field of study as a result of the increase of renewable energy generation, electrification of the transportation sector, and increasing demand for wireless electrical devices. Traditional capacitors have optimal performance with cycle times in the order of ms or s (e.g. power converters) while Li-ion batteries are suitable for applications require charge-discharge cycles of a few hours (for example, PV self-consumption) [12].

II. MATERIALS USED IN SUPERCAPACITOR

Fabrication of supercapacitor is done by using a combination of materials like activated carbon, metal oxide, separator and electrolyte. Activated carbon and metal oxide are collectively known as electrode materials and are applied on the electrode base in the form of a paste. Following section deals with venous materials used in fabrication of supercapacitors.

A. ***Carbon:*** The most researched electrode material is carbon. Activated carbon has been used as an electrode material in electrochemical capacitors since their invention due to its large accessible surface area and ease of supply [6]. Due to its inexpensive price, wide availability, highly porous nature, and excellent electrical conductivity, it is still a desirable alternative today. Depending on the method employed to manufacture the carbon, the actual double layer capacitance varies [7]. In the study work given, activated carbon Vulcun XC72 is employed in consideration of price and accessibility.

B. ***Metal Oxide:*** Due to their high specific capacitance and low resistance, metal oxides have long been a popular electrode material for high-energy, high-power supercapacitors. The characteristics of a supercapacitor are improved by using metal oxide and activated carbon [13]. As a result, it is included to boost performance. Electrodes may be built using a variety of metal oxides. The greatest results are obtained using ruthenium oxide, but because they are less expensive, manganese dioxide, vanadium oxide, and tin dioxide are receiving increasing attention [14]. The research provided uses manganese dioxide in consideration of this.

C. ***Separator:*** The sandwiching action of the separator keeps the two electrodes from making electrical contact with one another. Insulating and very porous, separator materials. They can transmit ionic charge because they're ion permeable [15]. Separators like polyethylene, paper, and nafion are frequently

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utilized. In the study project that was presented, polyethylene separator was employed.

Cost, size and shape are the important factors in the fabrication of flexible supercapacitor. Hence, it is vital to select appropriate materials in order to make it more cost effective and flexible. The following section deals with experiments conducted on various electrode shapes which is a step towards the development of flexible supercapacitors.

III. EXPERIMENTATION WITH VARIOUS SHAPES OF ELECTRODES FOR SUPERCA PACITOR

Part A. Formation of Supercapactior of Different Shapes

One may detect a change in capacitance as the electrode's shape changes. The forms of an electrode include a circle, a semicircle, a triangle, a rectangle, a square, and a rhombus. Making electrodes frequently uses rectangular shapes. These supercapacitors can be used to line the inside walls of vehicles such as the space shuttle and aeroplanes. Supercapacitors with a square shape can be stacked. Specific uses are possible for semi-circular supercapacitors. The versatility of the system is increased by using multiple forms for different purposes. To provide a point of reference, the electrode base area for each of these shapes is held constant at 3 square cm. Four electrode shapes are included in Table 1 along with their measurements.

Table 1: Various Shapes used to Make Electrode of Supercapacltor

Shape	Dimensions (in cm)
Rectangle	Length: 3,Breadth: 1
Square	Side: 1.73
Triangle	Base : 2, Height: 3
Semicircle	Radius:1.4

All materials and parameters—aside from electrode shape—are kept precisely the same in order to create supercapacitors using various electrode forms. Here are some of them:

a) The electrode base is constructed from a 3 square cm piece of stainless steel wire mesh.

b) Aqueous paste with 0.60g of activated carbon and ethanol (solvent) is applied to a cathode plate.

c) Aqueous paste with 0.30g of activated carbon, 0.30g of manganese dioxide, and ethanol (solvent) is added to the anode plate.

d) 11.3g potassium sulphate is used as electrolyte with molarity 0.73 Molar.

e) Supercapacitor is charged to a maximum voltage of 2.20 V.

The stainless steel wire mesh is properly limited for the extraction of the electrode base. Two electrodes are removed from the gauge for one supercapacitor, and one electrode the cathode plate has an appropriate mixture of activated carbon and ethanol put to it. A appropriate paste of activated carbon, MnO2, and ethanol is applied to the anode plate-shaped electrode on the opposite electrode. Utilising a polyethelene separator, these electrodes are separated. For the seperators, adhesive (favibond) is used to stick them. Following the sticking, a pressing method is used to keep the electrolyte and electrodes apart.

Part B. Testing of Supercapacitor

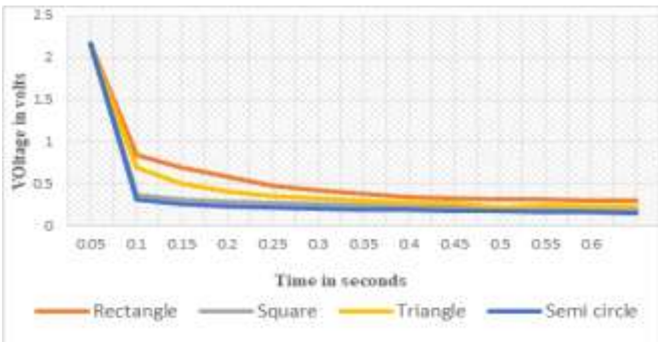
Supercapacitor testing may be done by charging and draining the supercapacitor. In the actual setup for supercapacitor charging and discharging, the supercapacitor is immersed in a solution of K2SO4 and then charged. Before being attached to the dc source to start charging, the supercapacitor is totally immersed in K2SO4 solution for 3 minutes. The supercapacitor is charged for one minute using 2 volts from a dc source. After the supercapacitor has been fully charged, it is drained by placing a voltmeter across it. As the supercapacitor is being discharged, the discharging current is measured.

IV. RESULTS AND GRAPHS

Table 2: Time and voltage reading of actual performances

Time	Voltage (in volts)			
in seconds	Rectangle	Square	Triangle	Semi-circle
0	2.16	2.16	2.15	2.17
5	0.85	0.37	0.7	0.31
10	0.7	0.32	0.5	0.26
15	0.59	0.29	0.41	0.23
20	0.48	0.28	0.36	0.22
25	0.43	0.26	0.33	0.21
30	0.38	0.25	0.3	0.2
35	0.35	0.24	0.28	0.19
40	0.33	0.23	0.27	0.18
45	0.32	0.22	0.226	0.18
50	0.31	0.21	0.25	0.17
55	0.3	0.21	0.24	0.17
60	0.3	0.2	0.23	0.16

Figure 1: Discharging graph of all shapes of supercapacitor



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V. CONCLUSION

As energy consumption grows, it is necessary to develop supplemental energy sources like batteries and supercapacitors. Supercapacitors are used in a wide variety of electrical devices, including amplifiers, oscillating circuits, filters, etc. The primary benefit of a supercapacitor is that its shape may be changed depending on the application. With numerous tests on various electrode shapes, we discovered that the rectangular electrode shape had the maximum energy density and could store the highest capacitance in comparison to other shapes.

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