ANALYSIS OF ELECTROCHEMICAL PARAMETERS FOR ACTIVATED CARBON SUPERCAPACITOR

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DEDICATION

I dedicate this work to every soul who brought colours into my life.

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First and foremost, I thank God for making all these possible and saving me at those dark times.

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ABSTRACT

This project investigates the correlation between the cyclic voltammetry (CV), galvanostatic charge-discharge (GCD), and electrochemical impedance spectroscopy (EIS) tests, which are the most common tests done to evaluate the performance of supercapacitor. The main contribution of this work is to study the characteristic of those tests, as well as knowing the relevance of using activated carbon (AC) electrode for the supercapacitor, when abundance of electrode options is also available in the market. This is achieved by comparing the electrochemical performance of the fabricated supercapacitor with the other materials' performances found in literature. To validate the findings, AC supercapacitor is constructed, which starts with creating AC electrode from commercially available AC powder. Cellulose paper, which used as the separator is sandwiched between two electrodes, before sealed inside the two-electrode test cell together with 1M H_2SO_4 solution as the electrolyte. The fabricated AC supercapacitor is then tested with the three tests stated before using Gamry Interface 1000. It is found that the CV test gives out the highest specific capacitance value while the EIS test gives out the lowest equivalent series resistance value. When compared with other materials, the performance of AC supercapacitor trails behind other novel material like metal-oxide supercapacitor. It is envisaged that this findings can be useful when choosing supercapacitor types for any application.

ABSTRAK

Kajian ini menyiasat hubungkait diantara ujian ‘cyclic-voltammetry’ (CV), ‘galvanostatic charge-discharge’ (GCD), dan ‘electrochemical impedance spectroscopy’ (EIS), yang merupakan ujian-ujian lazim bagi menentukan prestasi superkapasitor. Sumbangan utama bagi kajian ini ialah untuk mengetahui ciri-ciri ujian tersebut, disamping mengkaji kesesuaian penggunaan elektrod karbon diaktifkan (AC) berbanding bahan-bahan elektrod lain yang terdapat dipasaran. Hal ini dicapai dengan membandingkan prestasi elektrokimia superkapasitor yang dibina, dengan superkapasitor lain yang didapati dari kertas-kertas kajian. Untuk mengesahkan dapatan, superkapasitor AC dibina, bermula dengan pembuatan elektrod AC dari serbuk AC yang didapati di pasaran. Kertas selulosa yang digunakan sebagai pemisah, diapit oleh dua keping elektrod, sebelum dimeteraikan didalam sel ujian bersama larutan cecair asid sulfurik. Superkapasitor AC yang siap dibina kemudiannya diuji dengan tiga ujian yang dinyatakan awal tadi dengan menggunakan ‘Gamry interface 1000’. Kajian mendapat bahawa ujian CV memberikan nilai tertinggi bagi kapasitansi tertentu, manakala ujian EIS memberikan nilai terendah bagi rintangan siri yang setara. Kajian turut mendapati, apabila dibandingkan dengan bahan-bahan lain, prestasi superkapasitor AC agak ketinggalan berbanding bahan baru seperti logam oksida. Diharapkan agar dapatan-dapatan ini bermanfaat dalam pemilihan jenis-jenis superkapasitor bagi apa-apa penggunaan.

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LIST OF ABBREVIATIONS

AC	-	Activated Carbon
GCD	-	Galvanostatic charge/discharge
CV	-	Cyclic voltammetry
EIS	-	Electrochemical impedance spectroscopy
$Cs_{(CV)}$	-	Specific capacitance obtained through CV test
$Cs_{(GCD)}$	-	Specific capacitance obtained through GCD test
$Cs_{(EIS)}$	-	Specific capacitance obtained through EIS test
E_D	-	Energy density
P_D	-	Power density

LIST OF SYMBOLS

Ω	-	Ohm
°C	-	Degree Celsius
Hz	-	Hertz

CHAPTER 1

INTRODUCTION

1.1 Background

1.1.1 Energy Storage Devices

The World Health Organization (WHO), came out with a statistic of up to 160,000 of deaths per year are caused by both direct and indirect impact of climate change. The main cause identified of this environmental disaster is the production and usage of fossil fuels [1]. However. Given the deadly impact, it is unavoidable to use this resource before an affordable, realistic, and effective renewable energy source is implemented to meet the ever-increasing world energy demand.

Nowadays, there are a large number of energy storage devices with different energy conversion systems available, including mechanical, electrical and electrochemical systems. Flywheel power storage, supercapacitors and lithium-ion battery are some of the most commonly used devices [2]. Supercapacitors and lithium-ion battery have been the most interesting technologies to be studied for a long time, and they have garnered the attraction of investors from different fields of applications.

There are many factors that hinder the move towards the introduction of renewable sources of energy. There are many factors that hinder the move towards the introduction of renewable sources of energy. Some of them are scalability, specifications for inputs, and intermittency [3], which makes the said energy sources unstable and dangerous. However, with the increasing knowledge of environmental protection, several intensive works have been carried out in the quest for possible technologies to equip the power plants with renewable-green energy sources. The advancement of energy storage technology is intended to ensure the continuity of energy supply, thereby reducing the dependence on fossil fuels to fulfill the World energy demand [4].

1.1.2 Supercapacitor

Thanks to their high-power density, incredibly long cycle life, low maintenance costs, and healthy operating features, electrochemical capacitors, also called supercapacitors, are considered highly complementary to batteries. Their excellent performance makes portable electronics, power back-up systems, hybrid electric vehicles, and other electronic products promising for supercapacitor. One of the drawback of supercapacitor when compared to batteries is the low energy density characteristic. The performance of a supercapacitor electrode material depends largely on its structural engineering, which can significantly affect the electrical conductivity, electrolyte penetration and electrode ion transfer [5]. Researchers in the industry have made various efforts to improve the specific capacitance value of the supercapacitors with different types of electrode material aiming to enhance their storage and power output.

Figure 1.1 Commercial supercapacitor

1.1.3 Operation Principle of EDLC

Supercapacitors can be categorized into electrochemical double layer capacitors (EDLC), pseudocapacitors, and hybrid capacitors according to the charging storage mechanism. An EDLC is typically composed of two activated carbon electrodes, separated by a porous membrane separator and soaked in an aqueous or non-aqueous electrolyte. Electrical charges are deposited on the electrode surface by reversible ion adsorption / desorption processes while the opposite charged ions are adsorbed on the electrolyte side to form electrical double layers. With a high specific surface area and plenty of nanopores of the activated carbon electrodes, EDLC generally have a high-power density of up to 105 W / kg and a long life cycle [5]

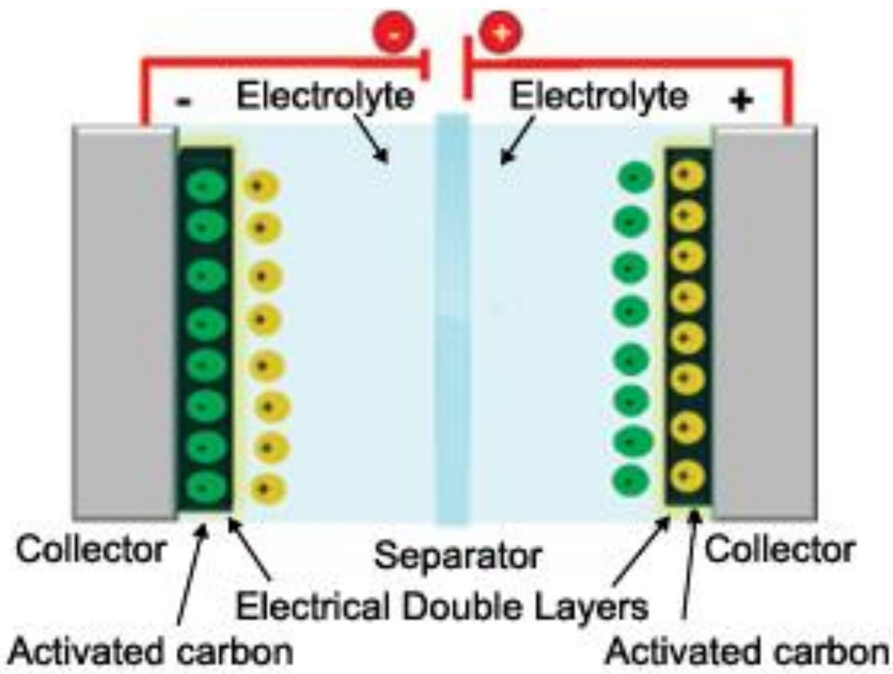

Figure 1.2 EDLC operation

1.2 Problem Statement

Through literature research conducted, it was found three types of tests; 1) cyclic voltammetry, 2) galvanostatic charge-discharge, and 3) electrochemical impedance spectroscopy, have been commonly chosen to assess the performance of the supercapacitor. However, limited studies have been carried out to explore the correlation between those three tests' results. This research investigates the correlation of these tests for an AC-based supercapacitor. The performance of the supercapacitor in comparison to other novel electrode materials-based supercapacitors is also carried out, thus, indicating the relevance of AC electrode.

1.3 Research Goal

There are three research objectives involved:

(a) To fabricate supercapacitor with a pair of activated carbon sheets as the carbon electrodes.

(b) To characterize the electrochemical performance of fabricated supercapacitor.

(c) To carry out a performance comparison of the fabricated supercapacitor to other supercapacitors with various types of electrodes.

1.4 Research Scope

(a) The research focuses on utilizing as precursor material for supercapacitor electrode

(b) The electrochemical performance is evaluated based three electrochemical tests; cyclic voltammetry, galvanostatic charge-discharge and electrochemical impedance spectroscopy tests.

(c) The supercapacitor performance is assessed in terms of specific capacitance.

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