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The Effect of Graphite as an Electrode Material towards Supercapacitor Discharging Time

Hizky Ronald Kurnia Jaya[1*], Wipsar Sunu Brams Dwandaru[2]

[1]*University of Edinburgh, United Kingdom*

[2]*Universitas Negeri Yogyakarta, Indonesia*

[1*] hizky.ronald@ed.ac.uk, [2]wipsarian@uny.ac.id

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ABSTRACT

This study aimed to 1) make a graphite-based supercapacitor, 2) characterize the graphite prepared, and 3) determine the effect of graphite mass as an electrode material towards the supercapacitor discharging time. This study consisted of three stages, namely: i) preparation of the graphite-based electrode material, ii) characterization of the graphite prepared, and iii) measurement of the supercapacitor discharging time with varying graphite mass. The characterizations of the graphite were carried out using an ultraviolet-visible (UV-Vis) spectrophotometer, X-ray diffraction (XRD), and particle size analyzer (PSA). The electrode material is made of graphite, epoxy, and aquades. Variations were made on the graphite mass deposited on the aluminum plate, namely, 1 g, 2 g, 4 g, 6 g, 8 g, and 0 g as a negative control. The results showed that the graphite was well deposited on the aluminum plate. The results of the UV-Vis characterization indicated that the graphite had an absorption peak at a wavelength of 301 nm. The XRD test showed the crystalline structure of the graphite with a sharp peak at 2□ of 26o. The PSA test showed that the dominant particle size distribution was 687 nm. The capacitors were given a voltage of 6 V for 1 minute. The measurement results showed that the discharging time increased as the amount of deposited graphite mass was increased. The electrode material with a mass of 8 g showed the longest discharging time, which was 12,000 seconds. The capacitors that were not deposited with graphite showed the shortest discharge time of 48 seconds after the power supply voltage was released.

Keywords: *Supercapacitors; Graphite; Electrode Materials*

ABSTRAK

Penelitian ini bertujuan untuk 1) membuat kapasitor berbahan dasar grafit, 2) mengkarakterisasi grafit yang telah dibuat, dan 3) mengetahui pengaruh penambahan grafit sebagai material elektroda terhadap waktu pengosongan kapasitor. Penelitian ini terdiri dari tiga tahap, yaitu: i) preparasi lapisan elektroda kapasitor berbahan dasar grafit, ii) karakterisasi grafit yang telah dibuat, dan iii) menentukan pengaruh massa grafit terhadap waktu pengosongan kapasitor. Karakterisasi grafit dilakukan menggunakan spektrofotometer ultraviolet-visible (UV-Vis), X-ray diffraction (XRD), dan particle size analyzer (PSA). Material elektroda terbuat dari grafit, epoksi, dan akuades. Variasi dilakukan terhadap massa grafit yang diendapkan pada plat aluminium, yaitu: 1 g, 2 g, 4 g, 6 g, 8 g, dan 0 g sebagai kontrol negatif. Hasil penelitian menunjukkan bahwa material elektroda terdeposisi dengan baik pada plat aluminium. Hasil karakterisasi UV-Vis menunjukkan bahwa grafit memiliki puncak serapan pada panjang gelombang 301 nm. Uji XRD menunjukkan struktur kristal dari grafit yang ditunjukkan dengan adanya puncak tajam pada 2□ sebesar 26o. Uji PSA menunjukkan distribusi ukuran partikel yang dominan adalah 687 nm. Kapasitor diberi tegangan 6 V selama 1 menit. Hasil pengukuran lama waktu pengosongan berbanding lurus dengan jumlah massa elektroda yang diendapkan. Bahan elektroda dengan massa 8 g menunjukkan waktu pengosongan paling lama, yaitu 12.000 detik. Kapasitor tanpa grafit menunjukkan waktu pengosongan paling singkat, yaitu 48 detik setelah tegangan catu daya dilepaskan.

Kata kunci: Superkapasitor; Grafit; Bahan Elektroda

1. INTRODUCTION

The current environmental crisis urges the world to develop sustainable sources of renewable clean energy, as well as efficient energy storage systems capable of powering electric vehicles and other electronic devices. Batteries and supercapacitors have been relied upon as two energy storage devices in the last decade. Secondary batteries have emerged as promising energy storage devices with high energy density. However, the power density of secondary batteries is limited due to slow ion insertion or intercalation processes (Zhang et al., 2022). On the contrary, supercapacitors have high power density. The combination of these two energy storage devices proves to be a viable solution in energy storage systems.

Supercapacitors exhibit several superior properties compared to batteries, such as being environmentally friendly, safer, having high power density, and a longer lifespan. Supercapacitors have high charge-discharge rates, enabling electronic devices to deliver significant performance in a relatively short period.

Supercapacitors have two energy storage mechanisms, namely electrical double layer capacitor (EDLC) and pseudo-capacitor. Carbon with a large surface area acted as the electrode material in EDLC. The capacitance of EDLC originates from the charge accumulated at the interface of the electrolyte and the electrode. In comparison to batteries, EDLC exhibits a significant difference in charge-discharge rates compared to secondary batteries (EDLC: 1-10 s vs. batteries: 0.5-1 hour), higher power density (EDLC: 500-10,000 W/kg vs. batteries < 1000 W/kg, and a longer lifespan (EDLC > 500,000 hours vs. batteries 500-1000 hours).

Supercapacitors generally consist of two parallel plates serving as current collectors, electrolyte solution, electrodes, and a separator. Graphite can be applied as an electrode in EDLC due to its specific properties, including a large surface area, cost-effectiveness, and environmental friendliness.

This research provides information on the process of preparing supercapacitors using graphite as an electrode and characterizing the graphite using ultraviolet-visible (UV-VIS) spectrophotometer, X-ray diffraction (XRD), and particle size analyser (PSA). The study also measured the discharging time of the supercapacitor with variation of the graphite mass.

2. METHOD

This was an experimental study. The experiment was conducted to investigate the effect of graphite mass as a supercapacitor electrode. Additionally, several characterizations were performed in this research, namely: multimeter, XRD, UV-Vis, and PSA, to gather information related to the graphite prepared in this study.

The focus of this research was on analysing the effect of graphite mass on the discharging time of the supercapacitor as an energy storage device. The research was conducted in three stages: graphite electrode preparation, graphite characterizations, and supercapacitor discharging time measurement. The first stage involved the preparation of the electrode material using graphite as the base material. The graphite used was characterized using XRD, UV-Vis, and PSA. The subsequent stage was the measurement of the discharging time of the supercapacitor, which was done using a multimeter and an MT-Tester.

The data analysis is conducted both quantitatively and qualitatively. Quantitative data are obtained from various characterization tests and as an energy storage device. Meanwhile, qualitative data are derived from the observation of the results of graphite layer deposition as the supercapacitor electrode.

The application of graphite as a supercapacitor electrode material was varied into five masses, i.e.: 1 g, 2 g, 4 g, 6 g, 8 g, and 0 g as a negative control. Measurements on all five mass variations were carried out at the same time and location. Quantitative data were obtained from the characterization results using a multimeter and MT-Tester. Qualitative data were assessed from the electrode material results on aluminium plates.

3. RESULT AND DISCUSSION

The composition of the electrode material mixture deposited in the supercapacitor is illustrated in Figure 1. Graphite, which is the main material of the electrode for charge storage, constitutes approximately 26% of the deposited electrode material mixture. The rest of the constituent materials are aquadest and epoxy glue.

The results of the deposited graphite onto the aluminium plates are depicted in Figure 2. It can be observed that the graphite adheres well to the aluminium plate, which serves as the current collector. The outcome of this deposition is an electrode material with water-resistant properties and mechanical stability due to the presence of epoxy adhesive. The resulting surface of the deposited graphite is slightly rough.

The graphite is characterized using a UV-Vis spectrophotometer with a wavelength range of 200 nm to 800 nm. This characterization aims to determine the absorption pattern at specific wavelengths. The graph of the UV-Vis characterization shows the relationship between absorption and wavelength (nm). The UV-Vis characterization result can be seen in Figure 3. The characterization result of graphite shown in Figure 3 exhibits shouldering peaks at wavelengths of 301 nm and 363 nm. These shouldering peaks indicate the presence of carbon material in the sample. The higher these shouldering peaks, the more graphite is contained in the sample.

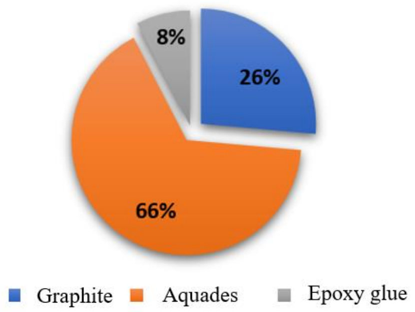

Figure 1. Composition of Electrode Material Mixture

Figure 2. Graphite Deposition Result.

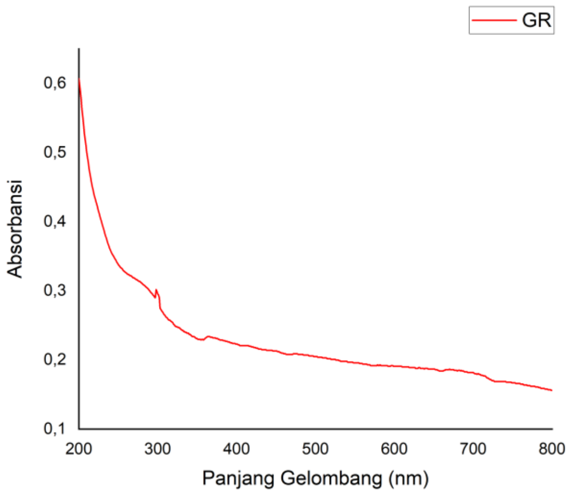

Figure 3. Result of the UV-Vis Characterization.

XRD characterization aims to determine the crystallinity of a material or sample. The data produced are in the form of a diffractogram that shows the relationship between intensity (I) and diffraction angle (2θ). The XRD range used is from 4° to 80°. The sample used in the XRD is the powder-form graphite sample. Figure 4 shows the characterization result of the graphite with XRD. The spectrum in Figure 4 displays several peaks detected at each 2θ. From Figure 4, it can be inferred that the graphite sample has a crystalline structure with a sharp peak at 2θ of 26º.

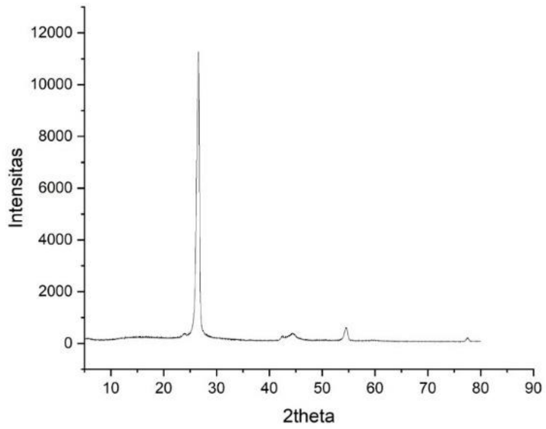

Figure 4. Diffraction Pattern of Graphite

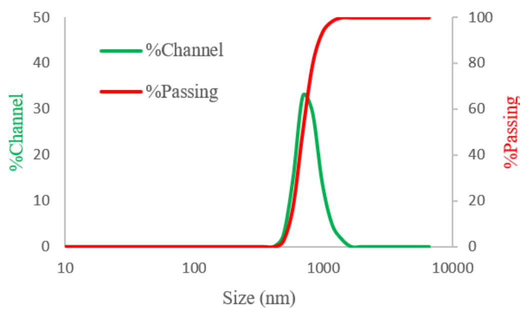

Figure 5. Particle Size Distribution of Graphite

The results of the PSA characterization test produce a graph depicting particle size on the X-axis and %channel and %passing on the Y-axis. %channel on the graph indicates the percentage of particles at a particular size, while %passing shows the cumulative percentage of particles smaller than a certain size. Figure 5 illustrates the particle distribution of graphite. Graphite has a dominant particle size distribution at 687 nm, accounting for 32% by volume, and 80% in the size range of 486 nm - 818 nm.

Graphite has been applied as an electrode in a supercapacitor. In this application, researchers conducted quantitative measurements in the form of voltage data and the discharge time of the supercapacitor. The amount of electrode material in the supercapacitor has been proven to influence the discharge time of the supercapacitor. In Figure 6, it can be observed that as the mass of the deposited electrode material increases, the discharge time of the supercapacitor also increases. This result is supported by the theory because supercapacitors store charge at the interface of the electrode material. Therefore, the larger the electrode surface, the more charge can be stored.

In these measurements, supercapacitors without deposited electrode material have the shortest discharge time, namely 48 seconds. Supercapacitors with electrode material of 1 g and 2 g show a longer discharge time, but it is not significant. This is because the electrode surface formed by the electrode material is still limited. Supercapacitors with a deposited electrode mass of 4 g show an increase in discharge time by 260 seconds. This is due to the electrode material that has been deposited being sufficiently extensive, forming a solid surface so that the layers of charge working at the interface of the electrode and electrolyte increase, and the mechanism of electrical double-layer storage begins to occur. With an electrode material mass of 6 grams, there is a more significant increase in discharge time reaching 1500 seconds. This is also supported by the extensive surface formed on the aluminium plate and the increasing layers of charge allowing for the storage of more energy. Supercapacitors with an electrode mass of 8 g show the most significant increase in this data with a discharge time of 12000 seconds. This demonstrates the formation of many layers at the interface of the electrode and electrolyte.

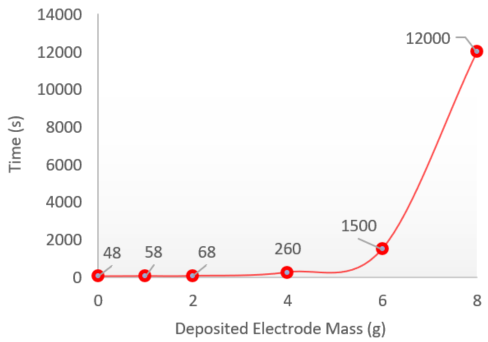

Figure 6. Supercapacitor Discharge Time

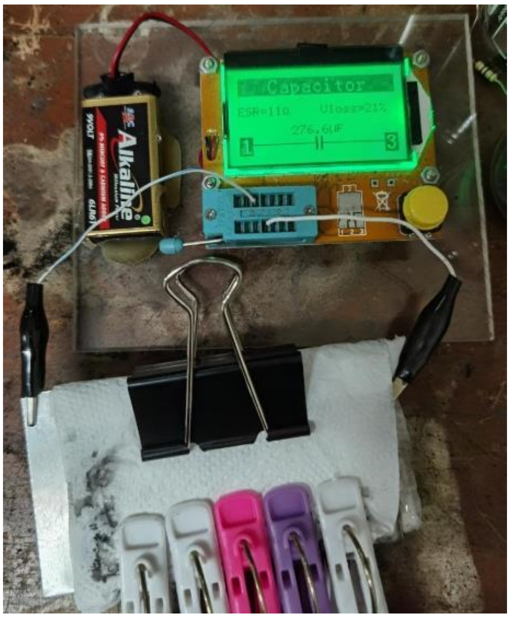

Figure 7. The Discharging Time Measurement

4. CONCLUSION AND RECOMMENDATION

The fabrication of supercapacitors using graphite as the electrode material has been successfully completed. Graphite characterization has been conducted using UV-Vis testing revealing absorption peaks at wavelengths of 301 nm and 363 nm. XRD testing result indicates that graphite has a crystalline structure. Furthermore, PSA result shows the graphite particle size distribution of 687 nm. The influence of the graphite mass on the discharging time is positive, i.e.: as the electrode mass increases the discharge time is exponentially extended. Further characterization of the supercapacitor can be conducted to measure output current and cyclic voltammetry. Further investigation can be carried out on graphite composites with other types of carbon as the electrode for supercapacitors.

5. ACKNOWLEDGEMENT

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