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Manufacture and Characterization of Supercapacitance Properties of Robusta Coffee Shell-Based Carbon Electrodes

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ABSTRACT

Supercapacitors, which are able to store large amounts of energy, are a major requirement in energy utilization. In this study, carbon electrodes were produced from robusta coffee shells. The carbon was activated with 0.5 M, 0.7 M, and 3 M of KOH. The results showed that the higher the concentration, the larger and more regular the pores on the carbon and the larger the size. Carbon is produced in an impure state. The specific capacitances produced with 0.5 M, 0.7 M, and 3 M KOH are 0.28 Fg^{-1}, 0.11 Fg^{-1}, and 0.10 Fg^{-1}.

Keyword: Supercapacitor Electrode, Specific Capacitance, Activated Carbon, Robusta Coffee Shell

ABSTRAK

Superkapasitor yang mampu menyimpan energi dalam jumlah besar merupakan kebutuhan utama dalam pemanfaatan energi. Pada penelitian ini dibuat elektroda karbon dari kulit kopi robusta. Karbon diaktifkan dengan 0,5 M, 0,7 M, dan 3 M KOH. Hasil penelitian menunjukkan bahwa semakin tinggi konsentrasi maka pori-pori pada karbon semakin besar dan teratur serta ukurannya semakin besar. Karbon diproduksi dalam keadaan tidak murni. Kapasitansi spesifik yang dihasilkan dengan 0,5 M, 0,7 M, dan 3 M KOH adalah 0,28 Fg^{-1}, 0,11 Fg^{-1}, dan 0,10 Fg^{-1}.

Kata Kunci: Elektroda Superkapasitor, Kapasitansi Spesifik, Karbon Aktif, Cangkang Kopi Robusta

1. Introduction

In recent times, efforts to provide electrical energy are a very important factor in encouraging development. Global energy consumption has reached alarming levels as the rapidly expanding global economy, increasing population, and growing human dependence on energy pose serious challenges to human health, energy security, and the environment, as well as revealing a growing need for the development of clean and sustainable conversion and storage of new energy [1], [2].

Supercapacitors as a type of electrochemical energy storage device have a higher energy density than batteries as well as fuel cells and conventional capacitors [3]–[5]. The capacitance and energy density of supercapacitors is highly dependent on the electrodes of the material used in the supercapacitor [6], [7]. The increased demand for supercapacitors indicates the need to explore new materials with large capacitance.

Coffee shell as one of the very large wastes in Indonesia has the potential to produce highly activated carbon because it has a carbon content of up to 45.3% of the mass of coffee grounds [8], [9]. Activated carbon is a material that can be utilized to make supercapacitor electrodes because it has a high surface area, chemical resistance, and good electrical conductivity [10].

This study aimed to produce supercapacitor electrodes using activated carbon from robusta coffee shells to produce the ability to store energy.

2. Method

2.1. Material

The main materials used in this research were coffee shells, hydrogen chloride (HCl), potassium hydroxide (KOH), and distilled water.

2.2. Preparation

The coffee shells were provided in a dry state and went through a carbonization process with a furnace at a temperature of 200°C for 2 hours until the coffee shells became charcoal. This carbonization process aimed to remove impurities of raw materials so that the carbon content could increase. The result obtained was charcoal, which was then filtered with a sieve size of 100 mesh. Furthermore, KOH activators with concentrations of 0.5 M, 0.7 M, and 3 M were used to activate the carbon that had been obtained. Its purpose was as impregnation. Within 24 hours, the solution was then allowed to stand. Then by using an autoclave, heating was carried out, namely at a temperature of 120℃ for 2 hours. After the activation process was completed, activated carbon had been chemically formed with a certain surface area. After the activated carbon was formed, to remove the remaining impurities, washing was carried out using a 1 M HCl solution and then rinsing with aqueous to eliminate the effect of the HCl solution. Next, the activated carbon was dried in the oven for 12 hours at a temperature of 120℃. This aimed to remove the water content that was still present in activated carbon. Then, the manufacture of the supercapacitor carbon electrode was conducted; the sample was weighed 0.7 g as many as 4 samples in each variation to be molded into pellets using a hydraulic press at a pressure of 8 tons and polished using P1200 convex sandpaper to have a mass of 0.025 g – 0.030 g.

2.3. Characterization

The micrograph of samples was carried out by Scanning Electron Microscopy (SEM). The particle size of the sample was conducted by Particle Size Analyzer (PSA). While functional groups of samples were investigated by Fourier Transform Infra-Red (FTIR) Spectra. Furthermore, a specific capacitance test was conducted by the cyclic voltammetry (CV) method.

3. Result and Discussion

3.1. Analysis of Scanning Electron Microscopy (SEM)

The SEM graph of all samples can be seen in Figure 1. The result obtained indicates the presence of pores on the surface of activated carbon. At the time of the activation process, all the gaps from the carbon are released so that it opens the pores of the activated carbon of the coffee shells.

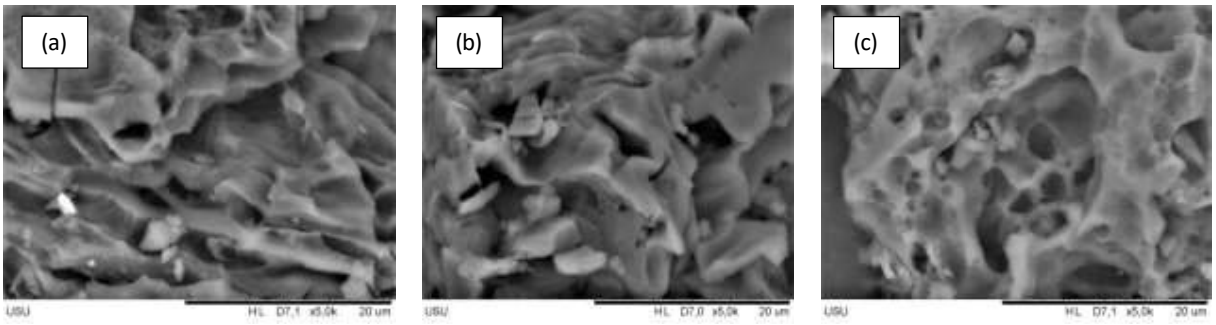

Figure 1. SEM pictures of a carbon electrode with a KOH activator of (a) 0.5 M, (b) 0.7 M, and (c) 3 M with 5000 times magnification.

Figure 1 shows that the greater the concentration of the activator, the more numerous and regular pores will be. The results of the SEM analysis found that if the concentration of activated carbon activators used is higher, then the pores produced are more numerous and the structure is more regular. These results indicate that the resulting sample has been activated.

3.2. Analysis of Fourier Infra-Red Transform (FTIR) spectra

Figure 2 provided the FTIR spectra of the samples. Upon conducting an FTIR analysis, it was determined that the resulting activated carbon contains functional groups such as O-H, C=C aromatic, C-H, and C-O.

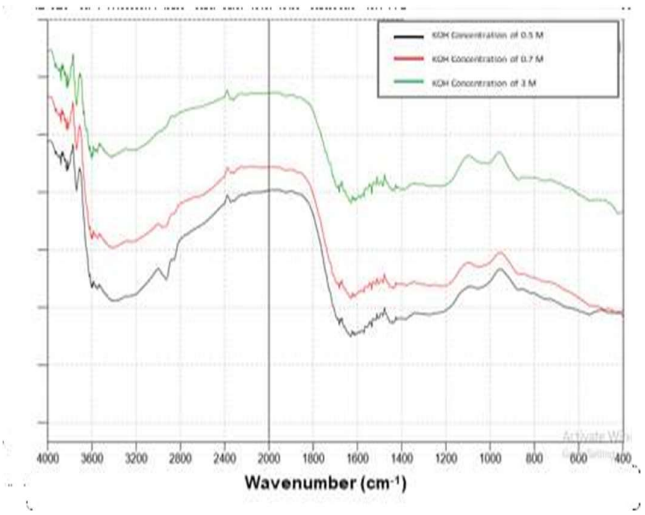

Figure 2. FTIR spectra of a carbon electrode with a KOH activator of 0.5 M, 0.7 M, and 3 M

3.3. Particle size analysis with PSA

Particle size analysis in this study proves that the greater the concentration of KOH activator carbon used, the larger the grain size of the particles produced. The grain sizes of activated carbon particles of carbon electrodes with KOH of 0.5 M, 0.7 M, and 3 M are 3.19962 µm, 6.38426 µm, and 7.03987 µm, respectively. Based on the results of this study, the particle size of the electrode is still too large to be applied to a supercapacitor electrode; in which a good electrode particle size is generally nanoscale

3.4. Analysis of specific capacitance with cyclic voltammetry (CV)

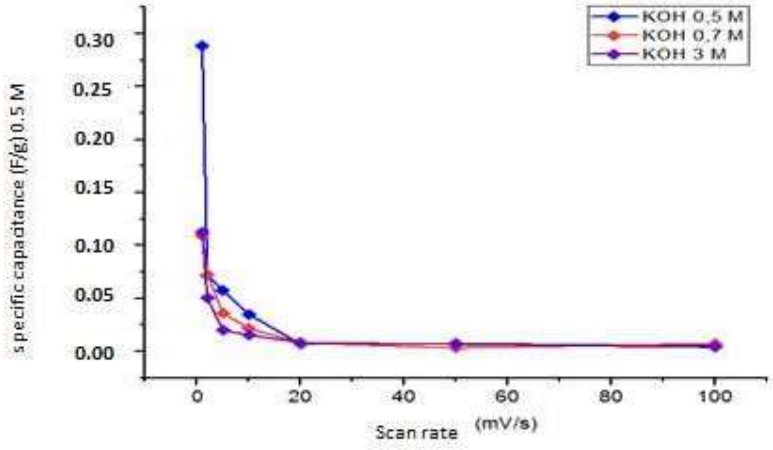

Figure 3. Variations in scan rate against specific capacitance values

Figure 3 shows that the highest specific capacitance was 0.28866 F/g at a concentration of 0.5M, 0.11236 F/g at a concentration of 3 M, and 0.109091 F/g at a concentration of 0.7 M for a scan rate of 1 mV/s. While the lowest specific capacitance value at a scan rate of 100 mV/s is 0.005361 F/g at a concentration of 0.5 M, 0.007818 F/g at a concentration of 0.7 M, and 0.004157 F/g at a concentration of 3 M. Higher concentrations of KOH result in a decreasing specific capacitance value of the carbon electrode. This can be seen in the scan rates of 5 mV/s, 10 mV/s, and 100 mV/s.

4. Conclusion

To conclude, the highest specific capacitance values were 0.28866 F/g at a concentration of 0.5 M, 0.11236 F/g at a concentration of 3 M, and 0.109091 F/g at a concentration of 0.7 M for a scan rate of 1 mV/s. While the lowest specific capacitance value at a scan rate of 100 mV/s is 0.005361 F/g at a concentration of 0.5 M of 0.007818 F/g at a concentration of 0.7 M and 0.004157 F/g at a concentration of 3 M. This study shows that the greater the concentration value of the KOH activator, the lower the specific capacitance value. The specific capacitance value of the resulting supercapacitor electrode is not eligible to

be applied as a supercapacitor electrode because the highest specific capacitance value produced is far from the specific capacitance value of some of the studies that have been conducted.

5. Acknowledgments

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