IPC

Indonesian Physics Communication

Department of Physics, Universitas Riau, Pekanbaru, Indonesia
p-ISSN 1412-2960 | e-ISSN 2579-521X

Vol. 21 | No. 3
November 2024

Web: https://kfi.ejournal.unri.ac.id
E-mail: kfi@ejournal.unri.ac.id

Synthesis and characterization of activated carbon based on young coconut fiber as a supercapacitor electrode

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ABSTRACT

Supercapacitor is energy storage devices consisting of electrodes, electrolyte, current collectors, and separator. In this research, carbon electrodes are made from young coconut fiber biomass (SKM) waste using $ZnCl_2$ 0.5 M as activation agent and variations in physical activation temperatures. Carbon electrodes preparation begins with a pre-carbonized process of 200ºC temperatures for 1 hour and 30 minutes, chemical activation using $ZnCl_2$ 0.5 M as activation agent, then the carbonization process uses N_2 gas as well as physics activation using CO_2 in temperature variation of 700ºC, 750ºC, and 800ºC. Analysis of the nature of electrodes cell capacitor based fiber young coconut fibers sample shows that the activation physics 750ºC sample is best, agreeble with the density of carbon electrodes declined by 40.43% after the carbonization-activation process. Carbon electrodes represent semicrystalline based on the characterization of the X-ray diffraction, marked with a ramp peak at 2θ at about 24º and 45º. The SKM-750 has a highest of L_c/L_a ratio an average number of microcrystalline inner layers (N_p), are 0.9 and 3.55. SKM-750 has the highest of specific capacitance value, namely 245.45 F/g.

Keywords: Activated carbon; electrode; physical activation; supercapacitor; young coconut fiber

Received 15-09-2023 | Revised 12-10-2023 | Accepted 02-11-2024 | Published 30-11-2024

INTRODUCTION

The energy crisis is one of the biggest problems in modern life, because energy supplies are running low. The solution that can be done to overcome this energy crisis is to use electrical energy to prepare for future energy. The use of very large energy in everyday life indicates the need for electrical energy storage media that is also very strong and durable.

This storage device has the attention of every country. One of them is a supercapacitor. Supercapacitors are widely used in industrial power and memory backup systems and energy management [1]. Supercapacitor components consist of electrode materials, electrolytes, current collectors, and separators. All components contribute to the performance of supercapacitor storage, but electrode and electrolyte materials play an important role [2]. One important component of a supercapacitor is the electrode. This electrode can affect the capacitance value that will be produced by the supercapacitor. The electrode is in the form of activated carbon which can be produced from biomass (organic material) which goes through a chemical and physical activation process.

Biomass that has the potential to be used as a carbon electrode in a supercapacitor is young coconut fiber. Coconut is a tropical plant that has long been known to the public. Coconut is a commodity strategy that has a social, cultural and economic role in the lives of Indonesian people. Young coconut fiber is the largest component of a coconut, the outermost part of the coconut fruit that wraps the coconut shell. The thickness of the coconut fiber ranges from 5 – 6 cm consisting of the outer layer 8 (exocarpium) and the inner layer (endocarpium). Young coconut fiber consists of fiber and also cork which functions to connect one fiber to another. Each coconut has 0.4 kg of fiber consisting of 30% fiber [3].

Young coconut fiber contains tannin compounds or tannic acid around 4.28%, while young coconut cork contains tannin compounds around 5.62%. Tannin has antibacterial activity against *Eserichia coli* and *Staphylococcus* *aureus* [4]. Young coconut fiber also contains 29.4% lignin, 26.6% cellulose, and 27.7% hemicellulose [5].

RESEARCH METHODS

This research method explains the procedure for making carbon electrodes for supercapacitor cells based on young coconut fiber. Young coconut fiber is separated from its cork. then dried in the sun until constant mass. The pre-carbonization process uses an oven at a temperature of 200 ℃ for 1 hour 30 minutes and the sample is ground using ball milling for 20 hours. The sample is sieved using a sieve with a size of 53 μm to standardize the particle size of the carbon powder. The chemical activation process uses 0.5 M $ZnCl_2$ activating agent. The manufacture of pellets from carbon powder uses a hydraulic press with a pressure of 7.5 tons and is held for 2 minutes. The carbonization process is carried out by heating the pellets in a furnace at a temperature of 600℃ using Nitrogen gas (N_2). The physical activation process uses Carbon dioxide gas (CO_2) with temperature variations of 700℃, 750℃, and 800℃. The carbon electrode is soaked using distilled water until the pH is neutral. The manufacture of supercapacitor cells is made using several components, namely carbon electrodes, current collectors, Teflon, separators (softies surgical masks 2nd layer), and electrolytes (H_2SO_4). Each sample will be subjected to density calculations and x-ray diffraction analysis, as well as electrochemical properties testing using the cyclic voltammetry method.

RESULTS AND DISCUSSION

Density Analysis

Figure 1 is a graph of the density reduction of carbon electrodes before and after the pyrolysis process. This decrease in density is caused by the carbonization and physical activation processes which have a role in removing elements other than carbon. The decrease in density obtained occurs because of the reaction of H_2O with carbon so that there will be a break in the carbon chain which forms new pores and carbon electrodes [6]. The resulting pores will determine the surface area of the carbon caused by carbon particles breaking into smaller parts than before [7]. After pyrolysis, the density value of the monolith in each sample experienced a decrease of 0.563, 0.511, and 0.585 g/cm^3 respectively with a density percentage of 32.8%, 40.43%, and 31.46%. SKM-700 has the lowest density compared to SKM-750 and SKM-800. Judging from the results of the density reduction, it can be concluded that the SKM-750 sample is the sample with the best heating, because the increase in density causes the porosity to decrease so that the specific capacitance value will also decrease [8].

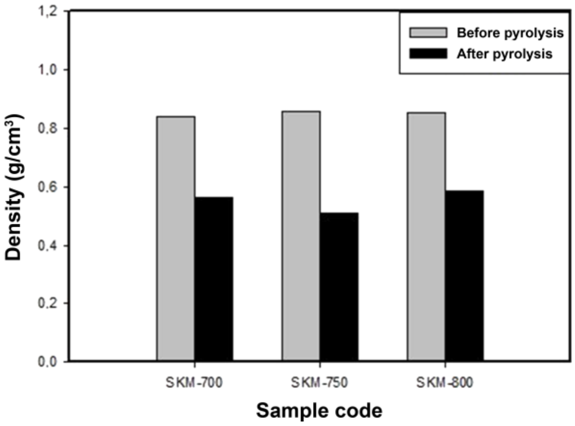

Figure 1. Carbon electrode density reduction.

X-ray Diffraction Data Analysis

The results of the X-ray diffraction pattern characterization show two peaks located on the hkl plane (002) and (100), where the 2θ angle on the scattering plane (002) and (100) on SKM-750 is 24.16º and 45.5º, while for SKM-800 it is 24.36º and 45.18º. The two gentle peaks mark the scattering angles that correspond to the amorphous structure of biomass-based carbon materials [9]. The sample with the largest high microcrystalline layer (L_c) is found in the SKM-750 sample with a physical activation temperature of 750ºC. The width of the microcrystalline layer (L_a) is inversely proportional to the height of the microcrystalline layer (L_c). The SKM-750 sample has the highest Lc value of 13.06 nm. Where a high L_c value indicates a large carbon surface [10]. It is concluded that the density and L_c value of the sample will affect the surface area [11]. The L_c/L_a ratio in each SKM-750 and SKM-800 sample is 0.9 and 0.8. This L_c/L_a ratio is related to the specific capacitance value that will be produced, because a high L_c/L_a ratio indicates a larger micropore volume, number of mesopores, and surface area so that the specific capacitance value will increase [12]. Table 1 shows that the SKM-750 sample has an N_p value of 3.55. This indicates that the microstructure of the sample has developed pores [13].

Table 1. Interplane distance and microcrystalline dimensions of carbon electrode.

Sample code	2θ		Interplane distance		Microcrystalline dimensions		L_c/L_a	N_P
	002	100	d_{002} (Å)	d_{100} (Å)	L_c (nm)	L_a (nm)		
SKM-750	24.16	45.5	3.68	1.99	13.06	14.46	0.9	3.55
SKM-800	24.36	45.18	3.65	2	11.61	14.46	0.8	3.18

Cyclic Voltammetry Analysis

Cyclic voltammetry test curves of SKM-700, SKM-750, and SKM-800 samples with a scan rate of 1 mV/s are shown in Figure 2. The CV curve on SKM-800 has the smallest area and the CV curve on SKM-750 has the largest area, this can affect the magnitude of the specific capacitance value in the supercapacitor cell. The wider the CV curve, the greater the charge-discharge current value, so the specific capacitance is high. The resulting CV curve also approaches the length size, where this shape is the ideal property of electrochemical double-layer supercapacitors (EDLC) [6].

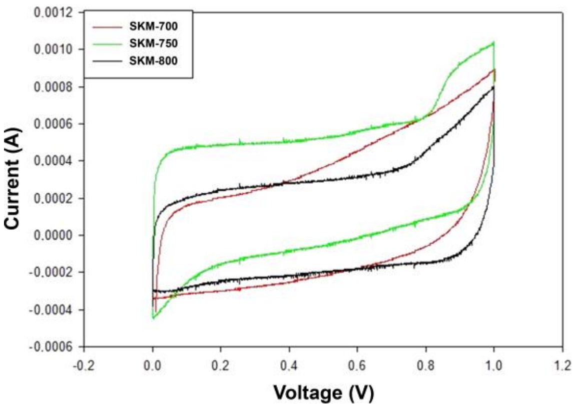

Figure 2. Cyclic voltammetry curve.

The specific capacitance value for each sample of SKM-700, SKM-750, and SKM-800 is 122.22, 145.45, and 95.93 F/g. This specific capacitance value is influenced by the physical activation temperature, where the higher the physical activation temperature, the faster the gasification reaction of volatile compounds, so that the carbon chain will be released and cause the pores formed to increase. However, if the physical activation temperature is too high as in the SKM-800 sample, it will affect the specific capacitance results. This happens because the temperature is too high will cause the carbon electrode structure to collapse, the inner wall channel becomes thinner and the adjacent pores will be interconnected. The high specific capacitance value in SKM-750 is due to having the lowest density value after the pyrolysis process of other samples. The low density value of the carbon electrode can increase the porosity which indicates the number of pores in the carbon electrode. The low physical activation temperature causes few pores to form in the carbon electrode. While the physical activation temperature that is too high damages the pore structure of the carbon electrode [14].

CONCLUSION

The results and discussion show that the temperature of 750°C is the optimum physical activation temperature for young coconut fiber samples. The temperature of 750°C is able to produce carbon electrodes with the highest density shrinkage percentage of 40.43%. The physical activation temperature of 750°C has high L_c, L_c/L_a, and N_p values so that it can increase the surface area of the carbon electrode. Analysis using cyclic voltammetry shows that the temperature of 750°C is able to produce a C_{sp} of 145.45 F/g.

REFERENCES

1. Miller, J. R. & Burke, A. (2008). Electrochemical capacitors: challenges and opportunities for real-world applications. *The Electrochemical Society Interface*, **17**(1), 53.
2. Samantara, A. K., Ratha, S., Samantara, A. K., & Ratha, S. (2018). Components of supercapacitor. *Materials Development for Active/Passive Components of a Supercapacitor: Background, Present Status and Future Perspective*, 11–39.
3. Awang, Y., Shaharom, A. S., Mohamad, R. B., & Selamat, A. (2009). Chemical and physical characteristics of cocopeat-based media mixtures and their effects on the growth and development of Celosia cristata. *American journal of agricultural and biological sciences*, **4**(1), 63–71.
4. Viju, N., Satheesh, S., & Vincent, S. G. P. (2013). Antibiofilm activity of coconut (Cocos nucifera Linn.) husk fibre extract. *Saudi Journal of Biological Sciences*, **20**(1), 85–91.
5. Paskawati, Y. A., & Retnoningtyas, E. S. (2017). Pemanfaatan sabut kelapa sebagai bahan baku pembuatan kertas komposit alternatif. *Widya Teknik*, **9**(1), 12–21.
6. Hanifa, Z., & Awitdrus, A. (2022). Pembuatan Elektroda Karbon dari Biomassa Sabut Kelapa Muda dengan Aktivator KOH Sebagai Aplikasi Sel Superkapasitor. *Indonesian Physics Communication*, **19**(1), 45–50.
7. Sudibandriyo, M. & Lydia, L. (2011). Karakteristik luas permukaan karbon aktif dari ampas tebu dengan aktivasi kimia. *Jurnal Teknik Kimia Indonesia*, **10**(3), 149–156.
8. Hartati, S. D., Taer, E., Sugianto, S., & Taslim, R. (2016). Pengaruh variasi suhu aktivasi fisika terhadap sifat fisis dan elektrokimia elektroda karbon superkapasitor dari limbah kulit pisang. *Spektra: Jurnal Fisika dan Aplikasinya*, **1**(2), 165–170.
9. Awitdrus, A., Hanifa, Z., Agustino, A., Taer, E., & Farma, R. (2022). Perbandingan larutan elektrolit H_2SO_4 dan KOH pada kinerja elektrokimia bahan elektroda berbasis karbon aktif sabut kelapa muda. *Indonesian Journal of Industrial Research*, **12**(1), 15–20.
10. Farma, R., Lestari, A. N. I., & Apriyani, I. (2021, October). Supercapacitor cell electrodes derived from nipah fruticans fruit coir biomass for energy storage applications using acidic and basic electrolytes. *Journal of Physics: Conference Series*, **2049**(1), 012043.
11. Miller, J. R. & Simon, P. (2008). Electrochemical capacitors for energy management. *Science*, **321**(5889), 651–652.
12. Farma, R., Deraman, M., Awitdrus, A., Talib, I. A., Taer, E., Basri, N. H., Manjunatha, J. G., Ishak, M. M., Dollah, B. N. M., & Hashmi, S. A. (2013). Preparation of highly porous binderless activated carbon electrodes from fibres of oil palm empty fruit bunches for application in supercapacitors. *Bioresource Technology*, **132**, 254–261.
13. Farma, R., Winalda, B., & Apriyani, I. (2023). The self-adhesive properties of carbon activated-like shape coin derived from Palmae plant waste and used as high-performance supercapacitor electrodes. *Journal of Electrochemical Energy Conversion and Storage*, **20**(2), 020902.
14. Simanjuntak, M. T., & Awitdrus, A. Fabrikasi elektroda karbon dari sabut kelapa muda dengan aktivasi fisika sebagai aplikasi superkapasitor. *Indonesian Physics Communication*, **19**(2), 65–68.