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Activated Carbon Electrode from Banana-Peel Waste for Supercapacitor Applications

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Abstract. Seven types of activated carbon electrode (ACM) have been produced from the banana peel waste for supercapacitor application. The difference type of the electrode was synthesized by the various conditions of carbonization and activation. The production of the ACM was begun by the milling process and molded by a solution casting technique. The next step was followed by drying, carbonization and activation process. Physical properties of the ACM were studied by the N_2 gas absorption-desorption method to characterize the specific surface area of the sample. On the other side, the electrochemical properties such as specific capacitance (C_{sp}), specific energy (E) and specific power (P) were resulted by calculating the current (I) and voltage (V) data from the cyclic voltammetry testing. Based on the data obtained the surface area of the ACM has a significant relationship with the electrochemical properties. The specific surface area (S_{BET}), C_{sp}, E and P were found the maximum value as high as 581m^2 / g, 68 F/g, 0.75 Wh/kg and 31 W/kg, respectively. Further more, this paper were also analyzed the relationship between electrochemical properties of supercapacitor with the degree of crystallization of the ACM.

INTRODUCTION

Activated carbon is a functional material that is widely used in various fields. One of the most advanced use of activated carbon is as an electrode for the application of energy storage devices such as supercapacitors and lithium batteries [1]. The high surface area properties and the cost to gain the material that relatively cheap were the key factor pointed in the selection of a carbon material as the electrode [2]. Some effort have been done to look for activated carbon with high surface area and low production cost, such as the utilization of biomass waste materials [3]. Various types of biomass waste have been reported as electrodes in the supercapacitor devices such as: sugar cane bagasse [4], corncob [5], rice husk [6], coconut shell fibers [7], oil palm empty fruit bunches [8], rubber wood sawdust [9] and cassava peel [10]. A wide variety of electrode materials study shown that surface area characteristic have a linearly corelation with the capacitive properties of a supercapacitors cells. In order to found a new raw material to produce activated carbon, banana peel is one of the urban waste materials are often encountered. Banana peel has a unique characteristics that have a kind of adhesive materials that can be used to produce a monolith carbon electrode without added adhesive material in the fabrication of supercapacitor cells.This uniqueness gives more intrest to select banana peel as raw material of carbon electrodes for supercapacitors cell because it can save on production costs. This research focused on study the use of waste banana peel as supercapacitor electrodes. Physical properties of electrode such as specific surface area, degree of cristalinity will be analyses and electrochemical caharacteristic of the electrode were studied in the form of the cell. The fabrication of carbon electrodes from banana peel waste were varied based on the condition of carbonization and activation process.

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EXPERIMENTAL

Carbon electrodes from banana peel waste has been prepared by various differences conditions of carbonization and activation. The carbon electrodes process begins by chopping the banana peel and blend it with a little water by using a blender. Slurry of banana peel was poured into a mold with size of 12x12 cm. Drying process is done to a temperature of 150 ^oC until weight of the sample would be constant. The samples were dried and formed such a sheet of paper. The sample were then cut with the size of 1x2 cm. The samples were then carbonized at different temperatures of: 500, 600, 700 and 800 ^oC and followed by activation process at a temperature of 800 C. Determination of carbonization profile based on the thermogravimetric analysis that has been previously reported. Some other samples were carbonized at a temperature of 600 C and continued by activation process at a temperature of 800, 850 and 900 C. Four selected samples with different carbonization and activation condition have been studied for a surface area and X ray difraction characteristic. The capacitive properties of all the samples were studied by fabricating the electrode for a supercapacitor cell . Capacitive properties was performed by cyclic voltammetry tehnique with a potential window of 0 to 500 mV at a scan rate of 1 mV / s in the 1 M H2SO4 electrolyte solution. The current, voltage and time were found for each supercapacitor cell will be use to calculate the specific capacitance ,the specific energy and specific power by using the following formula:

$$C_{sp} = \frac{(I_c - I_d)}{s\,m} \tag{1}$$

$$E = \frac{V\,I\,t}{m} \tag{2}$$

$$P = \frac{V\,I}{m} \tag{3}$$

Where Csp, I, s, E, V, t, m and P each are: specific capacitance (F / g), current density (A / cm^2), scan rate (mV / s), specific energy (Watt hour / kg), potential (Volt), time (hours), the mass of the electrode (g) and specific power.

RESULT AND DISCUSSION

Figure 1 shows the X-ray diffractogram for different sampel with various condition of carbonization and activation. The X-ray diffraction data indicate of broad peaks at an angle 2 theta of 24 and 44 degrees.These two peaks were appear at all samples are represented an amorphous materials. The presence a broad peaks at an angle of 24^0 and 44^0 were related to the plane of 002 and 100 for carbon materials [8]. Some sharp peak also exist in the sampel that indicated the existence of other elements that are crystalline characteristic.These sharp peaks associated with the presence of materials such as silica [11]. The difraction angle (2theta), the interlayer spacing (d), stack height (Lc), stack width (La) and the ratio of the Lc to La (Np) are listed in Table 1.

TABLE 1. X-ray difraction variabels for activated carbon samples from banana peel waste.

Samples	2θ (002)	2θ (100)	d (002) (Å)	d (100) (Å)	L_c (Å)	L_a (Å)	N_p
A800	24.973	44.691	3.563	2.026	13.095	15.235	3.675
A900	24.969	44.930	3.563	2.016	7.186	95.173	2.017
C500	26.581	46.449	3.350	1.953	9.885	9.148	2.950
C800	25.907	45.712	3.436	1.983	10.555	12.476	3.071

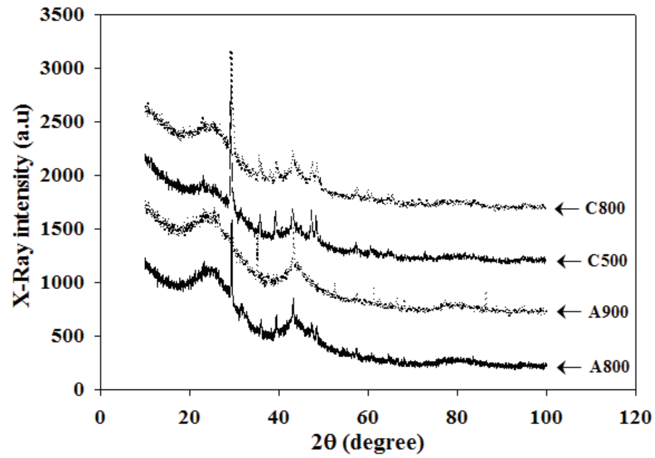

FIGURE 1. X-Ray difractogram for banana peel based activated carbon

Some selected samples also have been calculated the it's porosity properties such as specific surface area and were listed in Tabel 2. In this table the gas absorption volume and BET specific surface area data were found for different sampel with various condition of carbonization and activation. This table shows the maximum surface area for A800 and C500 samples as high as 580-590 m^2 / g . Specific surface area value of these two samples was in range commonly reported for activated carbon as supercapacitor electrodes [2].

TABLE 2. The porosity properties for banana based activated carbon with different condition of carbonization and activation.

Samples	V (cm^3/g)	S_{BET} (m^2/g)
A800	184.063	598.558
A900	83.249	282.865
C500	176.685	581.394
C800	113.650	393.333

Electrochemical properties for carbon electrode from banana peels were performed by using the cyclic voltammetry technique, the data was shown in Figure 2. Figure 2 shown the voltage and current density relationship for the sampels with various carbonization condition. In addition, the A800, A850 and A900 samples also has been studied. The forms of I-V curves was an almost ideal shape for supercapacitor cell with carbon based electrodes.From the figure at a cas coditions, in the relatively low voltages showed a significant increasing of the current density. these data exhibit such the process of ion diffusion into the pores occurred smoothly into the pore of meso and micro. Further increase in voltage also followed by an increasing in the current density. After a maximum potential window occurs discharge condition, a discharge current state where it looks almost symmetrical with cas current. Cycle cas and discal almost symmetrical that occur in the carbon electrodes shown a good capasitive characteristic of supercapacitor electrode.The difference of I-V area related to differences in specific capacitance value was generated by each electrode. The calculation of the specific capacitance, specific energy and specific power were shown in Table 3.

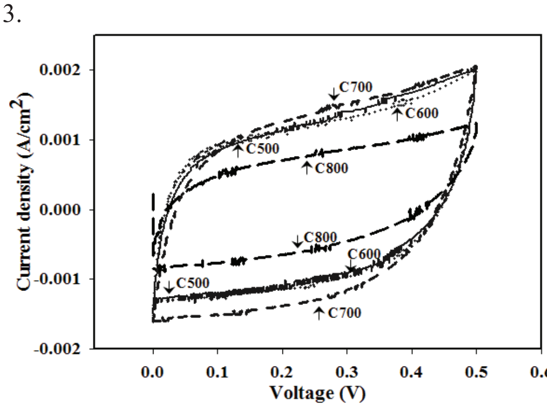

FIGURE 2. Cyclic voltammogram for banana based activated carbon supercapacitor

The data in the Table 3 and Table 2 clearly shows the existence of corelation the specific surface area value with specific capacitance, specific energy and specific power. The electrode samples with higher surface area demonstrate a good caracteristic in capacitance, energy and power of supercapacitor cells. Relations bettween surface area of the electrode and a capacitive properties of the supercapacitor cell that was a common in carbon based supercapacitors as had been reported previously [12]. The results of this study have shown the banana peel based activated carbon as a potential candidate for carbon electrode production for supercapacitor application.

TABLE 3. Capacitive properties activated carbon electrode from babana peel waste with different condition of carbonization and activation

Samples	Csp (F/g)	E (Wh/kg)	P (Watt/kg)
A800	55	0.632	26.443
A850	36	0.399	17.439
A900	11	0.148	8.745
C500	68	0.742	31.796
C600	59	0.568	25.653
C700	51	0.488	19.462
C800	33	0.333	14.418

CONCLUSION

All data and analysis has revealed that a carbon electrode from banana peel has a great potensial to be developed as a supercapacitor energy storage device. Carbonization and activation conditions affects the formation of physical properties of the carbon electrodes and also affects the electrochemical properties of the supercapacitor cells.

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