HIGH PERFORMANCE ELECTROCHEMICAL CAPACITOR BASED ON ACTIVATED CARBON DERIVE FROM PALM OIL KERNEL SHELL

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Introduction

Carbon, in a number of polymorphic forms such as amorphous carbon, activated carbon, carbon fibers, carbon nanotubes, and graphere, is used as energy a storage material due to several reasons including low cost, abundant, stability and scalability. Carbon is storing electrical energy based to electrostatic attraction in the electrode surfaces and electrolyte. No electron transfer takes place across the electrode interface and this charge storage process is non-Faradic. Charging and discharging process in the supercapacitors does not involve chemical and composition changes, such devices ɔsess high degree of cyclability (10^4 - 10^6 cycles).

The production cost to prepare activated carbon from coal is relatively high and demand with its original function as heat generator. Recently, tremendous effort has been given to synthesis activated carbon using waste material especially biomass precursor. Among them are corn grain[1], camellia[2], banana fiber[3], bamboo[4] and argan shell[5].

Malaysia is the largest producer of palm oil and the fraction of palm kernel shell (PKS) waste it produces is a considerable. There is no other value added industries based on this waste, thus, is was dump in landfill or burned to generate heat.

Here we report the feasibility synthesis of activated carbon using PKS waste and fabricated electrode for high specific capacitance energy storage device. It was demonstrated that, the specific capacitance > 200 F/g is archived which a good characteristic for carbon based energy storage and suggest that PKS is suitable candidate for replacing coal as the carbon precursor.[6]

Experimental

Preparation of Activated Carbon: The PKS waste was collected from oil mill factory and were washed thoroughly with distilled water to remove soil and dirt and then dried at 105 °C in an ɔn to remove moisture content. Chemical activation was performed using KOH as an activating agent. The PKS were mixed with the KOH solution at a weight ratio of 1:1 for 4 hours by continuous stirring. The impregnate PKS was then filtered and dried at 105 °C in an oven. The impregnate PKS was then carbonized in an electric furnace at heating rate of 10 °C/min and the final temperature of 500 °C with holding time of 2 hours. The resultant was washed repeatedly with 1 M HCl and then rinsed with distilled water until a neutral pH was obtained. The sample was then dried at 105 °C.

Electrode Preparation: The working electrodes were prepared as follows: 70 wt. % activated carbon sample was mixed with 15 wt. % Super P in an agate mortar until a homogenous black powder was obtained. To this mixture was added 15 wt. % polyvinyldifluoride (PVDF) as binder and a small amount of N-methyl pyrollidone (NMP) was then added to the the above mixture for homogeneity. Then the mixture was cast onto a nickel foam current collector of area ~1 cm^2. After drying overnight at 80 °C, the coated nickel foam was pressed to completely adhere the electrode material with the current collector.

Material Characterization: Powder X-ray diffraction was performed to investigate the structure and composition of the samples using Cu Kα radiation. The X-ray pattern was recorded in the scan range 2θ = 10-70°.XRD patterns were acquired on a Rigaku Mini flex II using Cu Kα radiation (λ = 1.5418 Å, kV = 30, mA = 15). Electrochemical measurements (cyclic voltammetry and galvanostatic charge-discharge) were carried out at room temperature using Autolab machine in a three electrode system using platinum wire and Ag/AgCl as counter and reference electrode respectively.

Results and Discussion

Figure 1 depicted the diffractogram of activated carbon from PKS. A broad peak centered at 2θ = 23° indicate the amorphous nature of the sample. This was due to reflection of (002) index of carbon which correspond to the staking structure of aromatic layers. The broadening of this peak can be explained in term of small dimension of crystallite perpendicular to aromatic layer on the precursor.

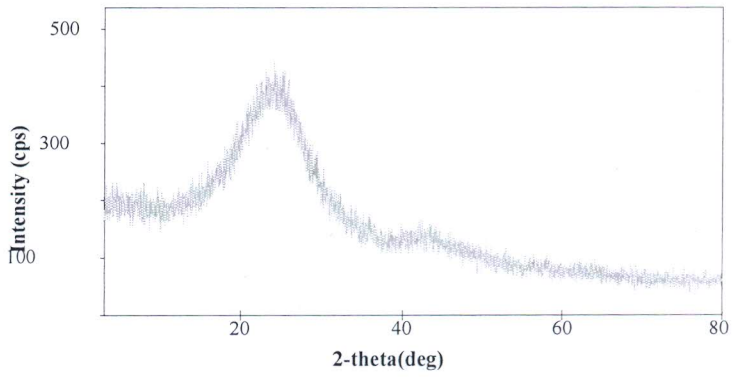

Figure 1. X-ray diffractogram of activated carbon.

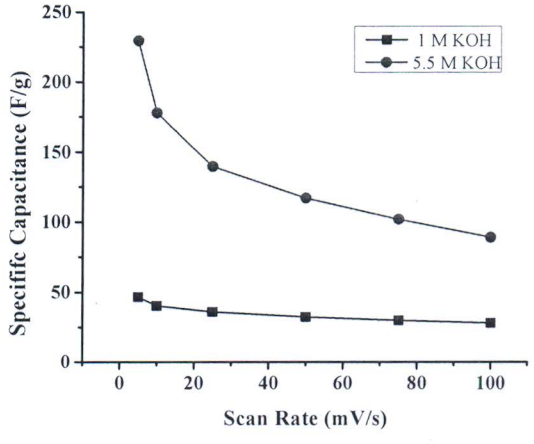

Figure 2. Cyclic voltammetry analysis of activated carbon.

Figure 2 shown the cyclic voltammetry analysis of activated carbon in 1 M and 5.5 M KOH electrolyte.Equation (1) is used to calculate specific capacitance on the analysis.

$$C_s = \frac{I}{m\Delta s} \qquad (1)$$

Where C_s, I, m and Δs are specific capacitance, anodic current, active mass and scan rate respectively.

At higher KOH concentration (5.5 M) and lower scan rate (5 mV/s), the specific capacitance is recorded 229 F/g and reduces with the increasing scan rate. It's shown that the specific capacitance value is drop to 89 F/g when it is scanned at 100 mV/s. For analysis of activated carbon using 1 M KOH, it gave specific capacitance of 47 F/g at scan rate 5 mV/s and the same trend is observed in capacitance value if the scan rate is increase which resulted only 28 F/g at 100 mV/s.

It can be explained that ions had enough time to diffuse into the internal and external surface of activated carbon if low scan rate is applied, while at the high scan rate the ions can only penetrated on the external surface. By increasing the concentration, the electrolyte resistance is reduces where rapidly interaction of ions with electrode surface is occur.

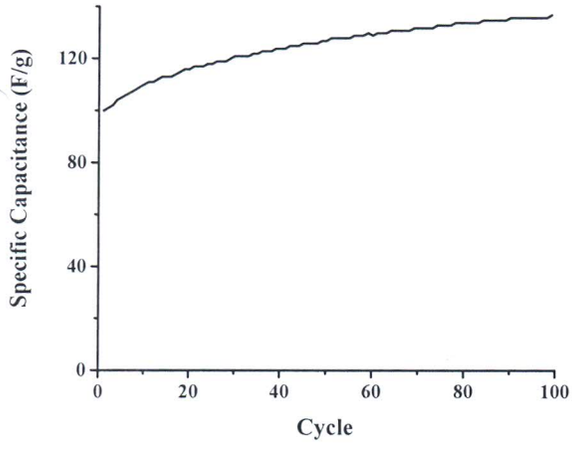

Figure 3. Charge discharge cycle of activated carbon at current density 10mA/g.

Stability study was carried out by mean of charge discharge cycling using 1 M KOH at current density 10 mA/g as depicted in Figure 3. For charge discharge analysis, the calculation of specific capacitance is based on Equation (2).

$$C_s = \frac{It}{m\Delta V} \qquad (2)$$

Where I, t, m and ΔV are applied current, discharge time, active mass and open potential respectively.After 100 cycle of charge-discharge analysis, the electrode is stable and recorded specific capacitance of 136.8 F/g (137%), which increase 37% from the first cycle.

Another study at higher electrolyte concentration is shown in Figure 4. The specific capacitance is 565 F/g when it is operated at 1 mA and reduces to 223 F/g when 15 mA/g current is applied. It is prove that the activated carbon can be used for long cycle and to its low cost precursor and synthesis of activated carbon from palm kernel shell, it is attractive material to be utilized in electrochemical capacitor applications.

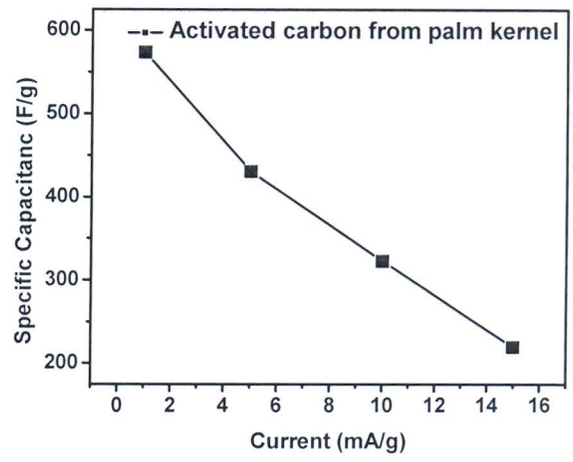

Figure 4. Charge discharge study at different current density using 5.5 M KOH electrolyte.

Acknowledgment

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References

1. Balathanigaimani, M.S., Shima, W.G., Lee, M.J., Kim, C., Lee, J.W., Moon, H., *Electrochemistry Communications,* **2008**,10, 868-871.
2. Juntao, Z., Liangyu, G., Kang S., Jianchun J., Xiaogang, Z., *J. Solid State Electrochem*, **2012**, 16, 2179-2186.
3. Subramanian, V., Cheng, L., Stephan, A.M., Nahm, K.S., Sabu, T.,Bingqing W., *J. Phys. Chem.*, **2007**, 111, 7527-7531.
4. Xinhong, Z., Lanfeng, L., Shanmu, D., Xiao C., Pengxian, H., Hongxia, X., Jianhua, Y., Chaoqun, S., Zhihong, L., Guanglei, C., *J. Solid State Electrochem*, **2012**, 16, 877-.882.
5. Abdelhakim, E., Zulamita, Z.B., Francisco,C.M., Carlos, M.C., *Bioresource Technology*, **2012**, 111, 185-190.
6. Burke, A., *Electrochim. Acta*, **2007**, 53, 1083-1091.