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Department of Electronics – Wayamba University of Sri Lanka

COCONUT SHELL ACTIVATED CARBON BASED SUPERCAPACITORS

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ABSTRACT

The development of energy-sustainable and energy-efficient economy depends on the ability to produce low-cost high-performance renewable materials for electrical energy storage devices. The electrical double layer capacitors (EDLCs) with activated carbon (AC) electrodes from natural precursors have attracted considerable attention due to their great cycle stability, combined with moderate cost and attractive overall performance including high specific surface area, high electrical conductivity, and relatively low price, easy and environmental friendly production in large quantities. The recent developments in the synthesis of such AC materials allow for the greatly enhanced specific capacitance in a wide range of electrolytes. This research project provides a summary of an attempt to use coconut shell activated carbon which is widely available in North Western Province and attempt in application for the electrodes used in supercapacitors. The electrodes were fabricated using CAC samples of 60%, 70% and 85%. Cells were tested for their cycling ability by using cyclic voltammetry, continuous charge-discharge tests and electrochemical impedance spectroscopy test with the different electrolytes performed Nano research Laboratory at Wayamba university of Sri Lanka. In these cells the best capacitance value of 0.1379F for the 1M KI (dil) electrolyte. It was observed for the CAC 85% sample for $5 mVs^{-1}$ scan rate.

Keywords: Coconut shell activated carbon, Supercapacitors, Electric double layer capacitance, Cyclic voltammetry, Electrochemical impedance, Adsorption

1.0 INTRODUCTION

Supercapacitors are electrochemical storage devices which are new energy storage devices with great application prospect based on the formation of the electric double layer at electrode/electrolyte interface. Comparing with rechargeable batteries they have many advantages owing to high power density, remarkable cycling performance, high safety, high-temperature stability, friendliness to environment[1]. Activated carbon is a carbonaceous, highly porous adsorptive medium that has a complex structure composed primarily of carbon atoms on behalf of high electrical conductivity, low cost, high chemical stability and high surface area it is also well suited as an electrode for supercapacitor[10]. There are chemical and physical activation processes. Physical activation procedure involves a two-step process, i.e. carbonization, followed by activation using steam, oxygen or carbon dioxide as an activating agent. However, in the chemical activation procedure, carbonization and activation processes occur in a single stage using chemicals as an activating agent such as potassium hydroxide (KOH), phosphoric acid and zinc chloride [1, 8].

Many types of materials are used in the fabrication of supercapacitor electrodes. Among them coconut shell activated carbon is used in this research project due to low cost, great cycle stability and their high availability in the North Western area. The other specific advantages are that the raw material can adsorb certain molecular species. To obtain good quality charcoal, fully dried, clean, mature shells were used[5]. Different kinds of electrolytes can be used in EDLCs with AC electrodes such as aqueous, organic, ionic liquid. In this study, the usage and the effect of CAC of different activity levels and electrolytes of KI (dil) and KOH (dil) on the performance of supercapacitors cells are reported.

2.0 EXPERIMENTAL

2.1 Preparation of electrode layers

Coconut shell activated carbon (CAC) powder (200mg) and distilled water mixture was prepared and pasted on Aluminium foil papers cleaned by ethanol using Doctor Blade method. The CAC samples which tested were belong to commercially available steam activated carbon. Particle sizes of CAC samples were measured by Fritsch particle analyzer. CAC samples were consisted of different activity levels such as 85%, 70% and 60% [9, 11].

2.2 Preparation of supercapacitor cell

Sandwich type supercapacitor cells were prepared by a pair of electrodes and separated by transparent paper in the Teflon sample holder. The electrochemical measurements were carried out at ambient temperature using KI (dil), KOH (dil) with the different concentrations of 0.3M and 1M as electrolytes.

2.3 Electrochemical measurements

Galvanostatic charge discharge cycle properties assembled with CAC samples of 60%, 70% and 85% respectively .They were measured within a constant current density of 1mA.Cyclic voltammetry (CV) was carried out in the potential range of -1V to 1 V using two electrode configuration using a computer controlled Potentiostat/Galvanostat (Metrohm AUTOLAB) to evaluate the capacitive characteristic at scanning rates of $5mVs^{-1}$, $10mVs^{-1}$, $15mVs^{-1}$ and $20mVs^{-1}$ with the start potential 0.2V, step potential was 1mV.The electrochemical impedance spectroscopy (EIS) was exploited in the frequency range of 100 Hz to 1MHz with an AC amplitude of ±10mV.

3.0 RESULTS AND DISCUSSION

3.1 Capacitance values obtained from cyclic voltammetry curves

Table 1. Capacitance values of the super capacitors

Activity level	Scan rate (mV/S^{-1})	Capacitance Values for each Electrolyte (F)	
		KI(1M)	KOH(1M)
60%	5	0.064	0.0031
	10	0.0366	0.0015
	15	0.0021	0.00098
	20	0.0016	0.00073
70%	5	0.0583	0.0154
	10	0.299	0.0091
	15	0.0198	0.0068
	20	0.0125	0.0056
85%	5	0.1379	0.0164
	10	0.0471	0.0086
	15	0.0279	0.0061
	20	0.0163	0.0048

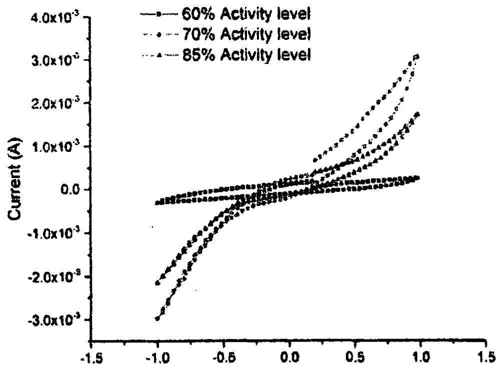


Figure 1: Cyclic Voltammograms (CV) obtained for different CAC cells at 5 mV s^{-1} with 1M KI (dil)

It indicates that the 85% CAC cell has the highest capacitance value for the 1M KI (dil) electrolyte. It has been shown that the use of redox electrolytes can increase the charge storage capacity of SCs. The oxidation and reduction processes are being carried out, hence the electrochemical reactions will take place on the porous carbon electrode due to ion movements the redox species may only be involved in one of the two electrodes, and the electrolyte is always shared between the positive and negative electrodes[5].

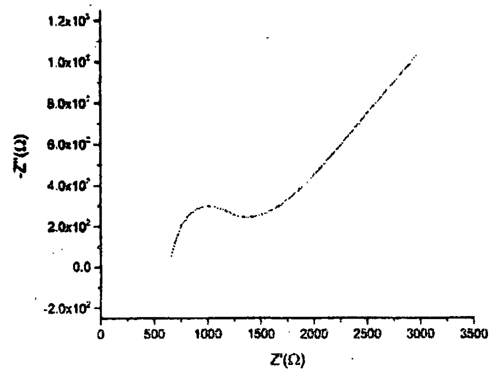
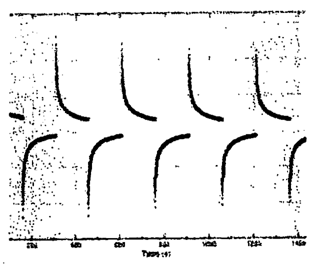
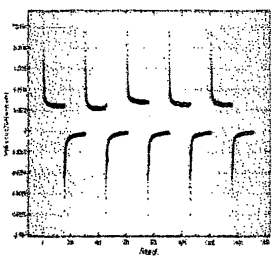


Figure 2: Impedance curves for 85% activation level using 1M KOH as electrolyte

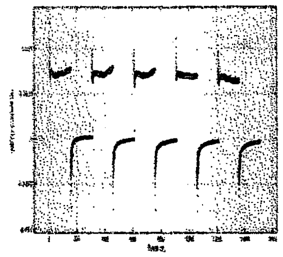
The EIS data expressed as Nyquist plots over the frequency range of 100Hz to1000 kHz for the supercapacitor cells. The current range is 100μA.



(a).Charge discharge curve for 60% CAC sample

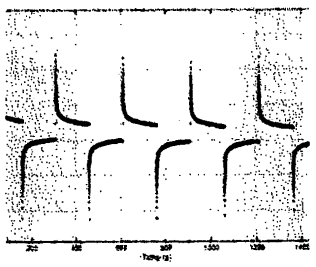


(b).Charge discharge curve for 70% CAC sample

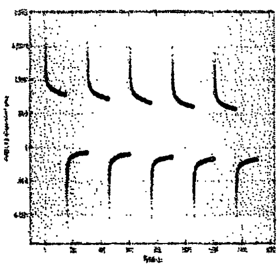


(c).Charge dischargecurve for 85% CAC sample

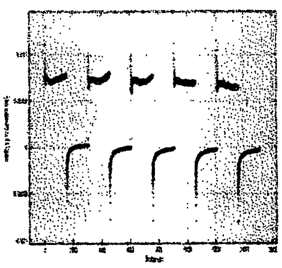
Figure 3: Charge discharge curves for different activation levels using 1M KI as electrolyte



(a).Charge discharge curve for 60% CAC sample



(b).Charge discharge curve for 70% CAC sample



(c).Charge discharge curve for 85% CAC sample

Figure 4: Charge discharge curves for different activation levels using 1M KOH as electrolyte

Galvanostatic cycling of supercapacitor electrodes was performed at a constant current of 1mA range. The discharge curves are linear in the total range of potential with constant slopes, showing perfect capacitive behavior in 60% CAC samples in both electrolytes.

4.0 CONCLUSION

Methods to fabricate supercapacitors using coconut shell activated carbon are found in this project research due to its high availability and cost effectiveness for assembling electrodes for the supercapacitors. The methods of assembling supercapacitors for the better performances by using different electrolytes and the range of activity levels of coconut shell activated carbon and their properties include particle size are found. The capacitance has increased by the activity level of 85% due to its' high specific area and the high concentration level of electrolytes of KI and KOH. The pore size of carbon materials is another parameter to be taken into account in order to optimize the capacitive performance.

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