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SUPERCAPACITORS BASED ON ACTIVATED CARBON AND POLYMER ELECTROLYTE

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ABSTRACT

The supercapacitors are characterized by fast discharge rate and easy for maintenance. Their demand is predicted to be most extensive in frequency regulation applications. The other area for significant growth is in regenerative braking for grid–connected light rail systems. In this research we fabricated a Supercapacitor using a commercially prepared Activated carbon which was sized to an area of 1 cm² and combinations of two electrolytes solutions; polymer electrolyte polyvinyl alcohol (PVA) and Phosphoric acid (H_3PO_4) assembled in an innovative supercacitor tester. The result indicates a relatively high efficiency of about 90 % and also exhibited long cyclability of life time under different voltage windows.

Key Words: Supercapacitor, Activated carbon, Charge-discharge, Cycle-voltammetry.

INTRODUCTION

The current pursue for energy sustainability have made electrochemical supercapacitors or ultracapacitors (M. Jayalakshm N. *et al.*, 2006; A. S. Graeme. *et al.*, 2009; D. Rathod M. *et al.*, 2009; X. Zhaoa H. *et al.*, 2009; M. Inagakia H. and Konnoa O., 2010) as a devices of utmost importance owing to their superior characteristics unmatched by other charge storage devices. Such characteristics include; high power densities (A. Balducci. *et al.*, 2005; T. C. Girija. and M.V. Sangaranarayanan., 2006; A. Lewandowski. and M. Galinski., 2007; M. Mastragostino. and F. Soavi., 2007; B. Ganesh. *et al.*, 2008; H. Yamada. *et al.*, 2008; M. Lazzari. *et al.*, 2008; X. Liu. and P.G. Pickup., 2008; A. Orita. *et al.*, 2010; P. Jampani A. *et al.*, 2010), at relatively high energy densities (less than that of lithium ion batteries (M. Inagakia H. and Konnoa O., 2010)) and long cycle life (B. Ganesh. *et al.*, 2008; A. S. Graeme. *et al.*, 2009; D. Rathod M. *et al.*, 2009; X. Zhaoa H. *et al.*, 2009; P. Jampani A. *et al.*, 2010) and also broader range of working temperature(M. Lazzari. *et al.*, 2008), high coulombic efficiency (high reversibility), environmental friendliness (no heavy metals used) (X. Zhaoa H. *et al.*, 2009; M. Inagakia H. and Konnoa O., 2010).

This paper is aimed at introducing yet another easy but effective method of fabricating an optimized supercapacitor which is being incorporated with activated carbon and solid polymer electrolyte (SPE).

MATERIAL AND METHODS

Commercial activated carbon (Carbon 50) of reasonable pore-size distribution was selected for this study. The electrodes were pressed from a combination of 70 wt% of activated carbon and 30 wt% of polyvinylidene floride (PVDF). A 20mL of acetone was added to the mixture in order for the solution to be easily blended in the laboratory blender. The resulting mixture of electrode was then poured in aluminium foil with a measured thickness of 2.5μm and then dried in an ovum for 14 hours at 100 ^{0}C.

The polymer electrolyte was prepared from 2 gram of polyvinyl alcohol in a 50 mL of distilled water and then stirred at 70 ^{0}C for 8 hours. Phosphoric acid (H_3PO_4) was then added to the aforementioned solution at different percentage rate (10 %-50 %) in a multiple of 10 until a desired percentage is reached and achieved (i.e. 50 %), this was due to the optimal conductivity ascertained. The sample was then dried for 14 days at room temperature.

Two electrodes of 1cm^2 sizes were built in a newly modified Teflon Swagelok-liked type system with steeled current collector. A 4 cm^2 of the already prepared polymer was used as the separator inside the Teflon Swagelok-liked type system. The gravimetric capacitance C expressed in Farad (F) per gram of carbon material was estimated by a galvanostatic charge-discharge (C-D) at constant current of 1mA using Multichannel charge-discharge machine (MCCD)

THEORY AND CALCULATION

As a background, the capacitance is defined as the ratio of charge (positive) stored Q to the applied voltage V;

$$C = \frac{Q}{V} \tag{3.1}$$

For a conventional capacitor, *C* is directly proportional to the surface area *A* of each electrode and inversely proportional to the distance between the electrodes.

$$C = \varepsilon_0 \varepsilon_r \frac{A}{D} \tag{3.2}$$

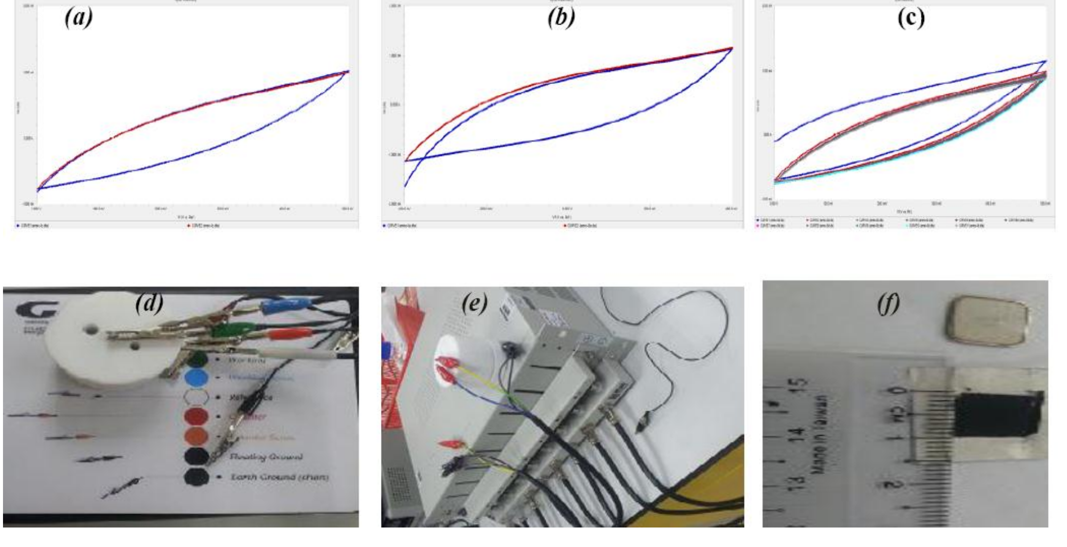
Where $\varepsilon_0 \varepsilon_r$ are constant of proportionality, ε_r as dielectric constant or "permitivity" of free space and ε_0 as the dielectric constant of the insulating material between the electrodes. So, the discharge capacitance of the unit cell was calculated from the equation given below

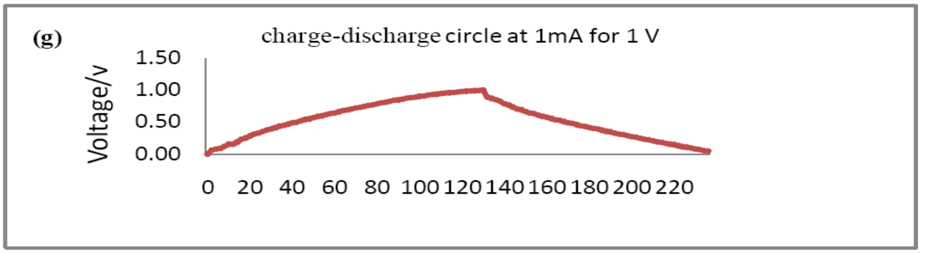
$$C = \frac{2(I \times \Delta t)}{M \times \Delta V} \tag{3.3}$$

Where *C* is the specific capacitance, *I* is the discharge current, *M* is the weight of the electrode and ΔV and Δt are voltage variation in time (with exception of *IR* drop) and discharge time respectively.

RESULT AND DISCUSSION

Figure (1) shows both galvanostatic charge discharge and cyclic voltammetry curves of the supercapacitor with polymer electrolyte. Using Gamry instruments (Fig. d), in the cyclic voltammetry (Fig a-c), the scan rates were set to be the same (10m V/s) but different voltage window and cycles. In Fig (a) it can be shown that the cyclability of the supercapacitor is very perfect even though the maximum current was set to only 0.5 mA and 1 V voltage window, but still the perfection of the curve was satisfactorily good when the current was increase to 1 mA (as in Fig b). The electrochemical properties of the cell can therefore considered as good looking at the effectiveness in the cyclability such as that in fig (c) with 10 cycles. Multichannel charge-discharge (MCCD) machine (Fig.e) was used to analysed and calculate the capacitance of the 1 cm^2 supercapacitor. From the profile of the Figures (*g* and *h*), the inverse V-shape of the curve with less internal resistance and voltage increment with time indicate the efficiency of the supercapacitor. The charging and discharging capacity of the supercapacitor was calculated to be 34.7 F/g and 38.39 F/g respectively. While the efficiency of the charging and discharging capacity of the supercapacitor were 81 % and 97.9 % respectively. The value of the capacitor was calculated to be 0.152 F.





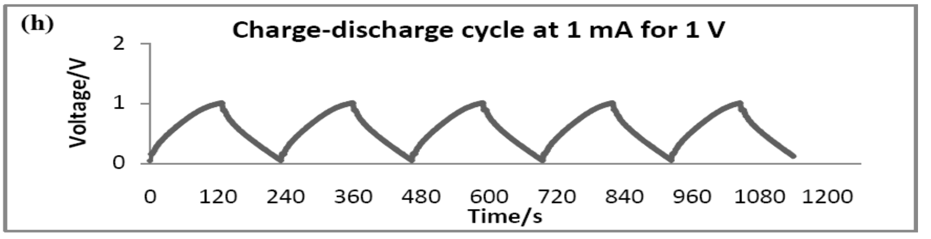


Fig.1. cyclic voltammetry using Gemry instrument at (a) Maximum current of 0.5 mA and scan rate of 10 mV/s, 1 cycle and voltage window of 1V (b) 1 mA, 1cycle and 1V(c) 0.5 mA, 1 V and 10 cycles (d) Gamry instrument (e) MCCD (f) 1 cm^2 electrode (g & h) C-D at voltage window of 1 V for 2 minutes at different cycles.

CONCLUSION

Supercapacitor has been fabricated from a commercial activated carbon (carbon 50) and polymer electrolyte from polyvinylidene floride (PVDF and Phosphoric acid (H_3PO_4) into a newly designed Teflon Swagelok-liked type system used for testing the capacitance of the supercapacitor. From the aforementioned discussions, it can be seen that the fabricated supercapacitor was able to achieve an average efficiency of 89.6 % for both charging and discharging. Though the capacity value was low, this can be achieved by enhancing the quality of the polymer electrolyte and reducing the thickness of the electrode.

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