# Capacitance Stability of Supercapacitor from Activated Carbon/PVDF Electrode

Lydia Rohmawati[1], Woro Setyarsih[2], Nuricha Anggraini[3], Sahara Hamas Intifadhah[4], Siti Holisa SP[5]

Physics Department
Universitas Negeri Surabaya
Surabaya, Indonesia
[1]lydiarohmawati@unesa.ac.id

*Abstract*—**The aim of research was to be aware stability of supercapacitor capacitance for 50 cycles. Supercapacitor device in this research was fabrication into sandwich form, that consist a pair of activated carbon/10 wt% PVDF electrode separated with hydrogel polymer. Furthermore do characterization using cyclic voltammetry for 50 cycles with 1 M $Na_2SO_4$ electrolyte solution at the scan rate 5 mV/s. The result of this research show that supercapacitor device with activated carbon/10 wt% PVDF capacitance stability 39 F/g at 50 cycles.**

*Keywords—Actvated carbon/PVDF; capacitance stability; supercapacitor.*

## I. INTRODUCTION

Supercapacitor is a energy storage device that many developed by many scientist. Supercapacitor is combining between rechargeable batteray which has high spesific energy and high power of dielectric capacitor [1]. Supercapacitor device consisting of a pair electrode separated with separator and filled by electrolyte solution. electrolyte solution that is often used are $H_3PO_4$ and $Na_2SO_4$ [2]. Electrode is the most important thing in the supercapacitor performance because of the storagee process happens in electrode. Nowadays, metal oxide trantitions (RuO, $Fe_3O_4$ dan NiO), carbon materials (activated carbon, carbon nanotube, and graphene) and conducting polymer has been often used as a supercaacitor electrode [1]. Activated carbon is a one of electrode materials that often used because have more advantages among easy to make, low cost, and have a large surface area [3]. Activated carbon can be obtain from commercial charcoal or waste, one of the organic waste is coconut shell. Activated carbon from coconut shell have a large surface area 414 $m^2$/g and specific capacitance 10 F/g [4]. This value of activated carbon still relatively low, because of this we need to combine with polymer binder. One of the polymer binder is mostly used is polyvinylidenedifluoride(PVDF) [5]. *Polyvinylidenedifluoride* (PVDF) is a thermoplactic fluoropolymer is have non reactive property and produced from polimerization of vinylidene difluoride. PVDF also known as a binding polymer that requires an organic solven, such *N-Methyl-2-Pyrrolidone* (NMP) [4]. According to experiment by Weng, et al (2010) [6] about characterization Double Layer Capacitor from dari carbon based electrode (coal tar), which is this carbon etching using KOH and added with solution of PVDF and NMP, with 20% compotition of PVDF, acquired that EDLC have

capacitance stabilty (around 120 F/g) an columbic efficiency (around 99%) on 200 cycles. According to Hasyim, et al (2011) about supercapacitor of activated carbon materials and electrolyte polymer, which 70wt % activated carbon and 30 wt % PVDF, have good electrochemical property with effectiveness of cycle is around 10 cycle on the voltammogram curve [7]. Pursuant to the research by Rohmawati, et al (2018) about variation scan rate electrode active carbon/10 wt%PVDF at cyclic voltammetry 5 mV/s until 50 mV/s with electrolyte solution H3PO4, showed at the scan rate 5 mV/s have the highest specific capacitance 86 F/g [5]. Therefore, in this research is aimed at finding out cycle stability of supercapacitor with activated carbon/10 wt% PVDF electrode and hydrogel polymer, at the scan rate 5 mV/s. In the future do characterization of cyclic voltammetry as much 50 cycle using electrolyte solution 1 M $Na_2SO_4$, with the hope of the supercapacitor that has been created to have the capacity stability of the 50 cycles.

## II. MATERIAL AND METHODS

### A. Materials

Materials required in sample preparation : gading coconut shells, natrium oxide (NaOH 0,5M), aquades,hydrochloric acid (HCl 1M), polyvinylidene flouride (PVDF), N-Methyl-2-pyrrolidone (NMP), polyvinyl alcohol (PVA), and ortho-phosphorid acid (H3PO4) with concentration 50 %.

### B. Methods

The method of preparation a supercapacitor device refers to a previous research [4], of the activated carbon preparation of coconut shells, the fabrication of activated carbon/PVDF electrode, and fabrication supercapacitor separator from hydrogel polymer. For fabrication activated carbon using carbonation method and chemical activation using NaOH solution. During the activation, carbon wet for 24 hours then calcination at the temperature 800°C for 5 hours. Then fabrication of supercapacitor electrode, activated carbon added to the solution consist of 10 wt % PVDF and NMP using mixing method for 30 minutes until homogenous. The separator is maked from hydogel polymer using sol-gel method, that is 2 gr PVA solved to the 50 ml aquades and stirrred at the temperature $70^0$C for 8 hours. Then added by $H_3PO_4$ until formed to clear solution, and dried in romm temperature for 14 days. Supercapaitor device prototype is

made in the sandwich form. That is between 2 electrodes added a separator then compressed at the pressure 1500 psi, and heated at the temperature 50°C for 30 minutes, to form a strong bond between these electrode. Then, characterization cyclic voltammetry at the potensial range 0-1 V with scan rate 5 mV/s, setting 50 cycle to know the cycle stability of supercapacitor. The result of this characterization then analyzed using equation (1) and (2) to know specific capacitance value of the supercapacitor [2]

$$C_{sel}(F) = \frac{\int idV}{\Delta V \times V_S} \qquad (1)$$

$$C_s(F/g) = \frac{2C_{sel}}{m} \qquad (2)$$

With *Csel* is cell capacitance (F), i is a discharge current (A), *Vs* is scan rate (V/s), ΔV is the potensial range (V), Cs is specific capacitance (F/g), and m is electrode mass (gram).

## III. RESULT AND DISCUSSION

Characterization of cyclic voltammetry of the supercapacitor device using electroyte solution $Na_2SO_4$ 1 M, and setting with 50 cycle. The result of this characterization show in voltammogram curve with relation between potensial and current (Figure 1).
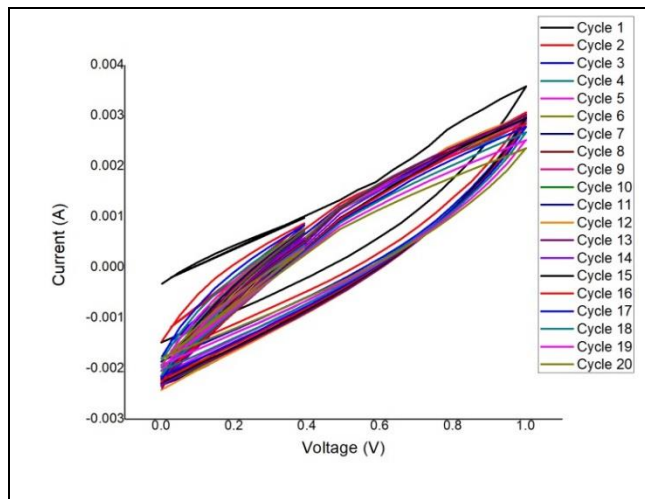


Fig. 1. Voltammogram curve for 20 cycles of the activated carbon/10 wt% PVDF electrode and hydrogel polymer

Based on Figure 1, shows a voltammogram curve for 1 to 20 cycles at a scan rate of 5 mV/s. The resulting curve is reversible and has certain cathodic and anodic currents, so that different loops appear for each cycle. This is because during the process of charging from the electrolyte to the surface of electrode on supercapacitor at different times as well as emptying the charge from the surface of electrode into electrolyte. It appears that the current response increases with the potential given to all cycles, causing the reduction and oxidation process to take place rapidly causing a limited ion tranfer to the surface of electrode [5]. In the first cycle, the resulting current is large at 3.5 mA when compared to the next

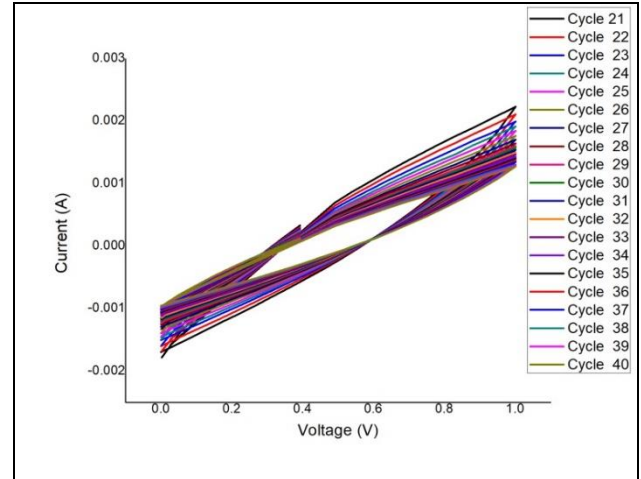cycle, so that the amount of charge stored on the surface of electrode is possible.

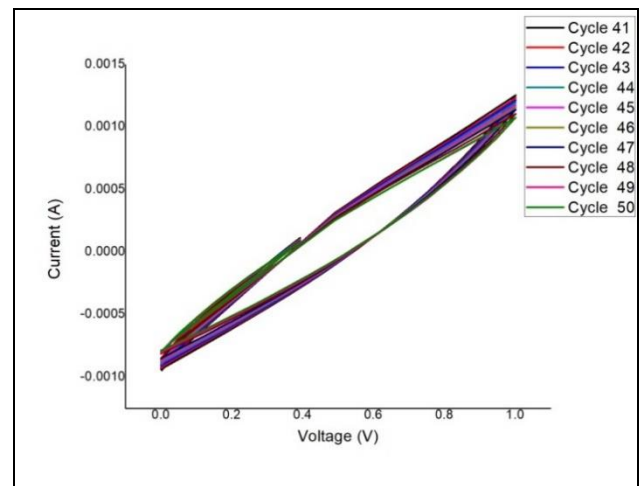

Fig. 2. Voltamogramm curves for cycle 21 until cycle 40



Fig. 3. Voltammogram curves for cycle 41 until 50 cycles

In Figures 2 and 3 shows the voltamoggram curves for cycles 21 to 40 and 41 to 50 cycles. In the 21 cycles the current response is arround 2.3 mA, allowing the amount of charge stored in the activated carbon/PVDF electrode when compared to the next cycle, with a long time for the ion adsorpstion process to the surface of electrode and desorpstion of the ion into electrolyte. Also for Figure 3, the 41 to 50 cycle has descreased current response, i.e. starting from 1.3 mA to 0.9 mA during the reduction or binding process of the ion, thus affecting the small of charge stored in the electrode, when compared to the 1 to 40 cycle. Curve shapes such as Figure 1, 2 and 3 indicate that at scan rate of 5 mV/s with 50 cycles, the activated carbon/PVDF electrode acts as a resistive capacitor because too much electrical charge is attached to the working electrode [8].

Using the equation (1) and (2) obtained capacitance value for 50 cycles voltammetry.
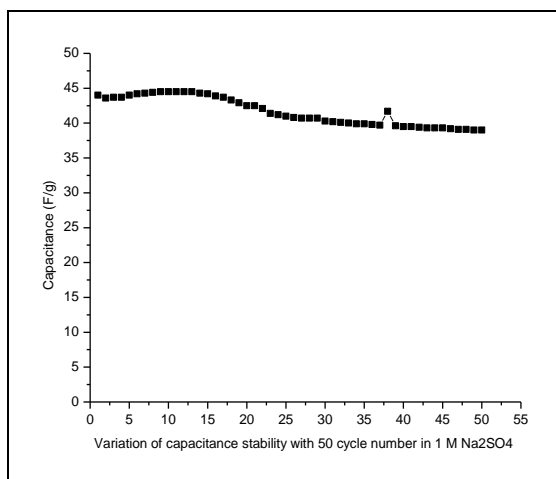
Fig. 4.    Capacitance stability for 50 cycles of cyclic voltammetry

Figure 4 shows the stability of capacitance at 50 cycles in $Na_2SO_4$ electrolyte solution. In the first cycle has a capacitance value of 44 F/g, after that  in the 2 to 4 cycle, the capacitance velue decreases to 0.91%, which is 43.7 F/g. the starting the 5 to 15 cycles, the capacitance value tends to be stable, i.e. 44.5 F/g. The 16 to 39 cycles has descreases to 10.3%. The decreasing capacitance value is due to the accumulation of ions on the surface of electrode due to the length of the diffusion process between the electrolyte and surface of electrode, which causes weaking of ion binding by the electrode during the reduction process and this effects the oxidation process. Capacitance on electrodes starts to stabilize in the 39 to 50 cycles, which is equal to 39 F/g. this means that the diffusion of ions on the surface of electrode has been saturated. In this study, 50 cycles setting was done, feared more than 50 cycles, the sample of this study was damaged. But in these 50 cycles, the sample still shows reversible voltammogram curves. This is because the sample is hydrophobic, meaning it is difficult to absorb water, so that up to the 50 cycles, the sample still shows good supercapacitor performance, with a capacitance stability of 39 F/g in the 39 to 50 cycles. This result is different from that carried out by Zhu, et al., (2016) regarding the effect of binders on supercapacitors performance, activated carbon/10 wt% PVDF electrodes have capacitance stability of 78.2 F/g

for 2000 cycles [9], where the electrode is activated carbon as an active material and carbon nanotubes are used as a conductive agent. However, the results of this study are better ehen compared to those carried out by Hasyim, et al (2011), where commercial activated carbon/30 wt% PVDF electrodes with hydrogel polymers, obtained good cell electrochemistry in 10 cycles with a scan rate of 10 mV/s [7].

## IV.   CONCLUSION

The result of this experiment show that supercapacitor device with activated carbon/10 wt% PVDF have stability capacitance 39 F/g at the 50 cycles. Each cycle shows reversible voltammogram curve with certain loop area.

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