

# PERFORMANCE ANALYSIS OF $\text{LiVO}_3$ -ION BATTERY WITH CARBON (*Ipomoea Aquatica*) AS ANODES

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## ABSTRACT

This research was conducted by utilizing water spinach which is found in swampy areas as new material for support in battery. Water spinach stems were separated used as carbon precursor. The carbon was prepared through hydrothermal and pyrolysis processes. The battery was constructed using the carbon anode and cathode from  $\text{LiVO}_3$ . The  $\text{LiVO}_3$  was produced by using hydrothermal process of  $\text{LiCl}$ ,  $\text{V}_2\text{O}_5$ , and  $\text{NaOH}$  in  $200^\circ\text{C}$  30 bar for 16 hours. The performance of the battery was evaluated using cyclic voltammetry and galvanostatic charging – discharging methods on potentiostat. The electrolyte used was  $\text{LiCl}$  in liquid or gel electrolyte with concentrations of 10%, 20% and 40%, respectively. The binders were used PU and melamine. Material characterization reveal that the carbon has crystalline phase, conductivity and pores which therefore carbon has the capability to be used as anode precursor. The evaluation of battery performance showed that the highest current value was found in battery with 40%  $\text{LiCl}$  of liquid electrolyte and polyurethane binder, that is 0.22 A. The highest power  $5.36 \times 10^{-1}$  W, energy  $1.80 \times 10^{-2}$  Wh, and capacity  $8.94 \times 10^{-1}$  F was found in battery with 40%  $\text{LiCl}$  of liquid electrolyte with binder PU. The lowest battery discharge slope 0.0039 was found in 40%  $\text{LiCl}$  of liquid electrolyte with PU binder. These findings provides an alternative to the use of materials in Lithium ion batteries without compromising the performance of their application.

**Keywords** : LIB, Carbon, Binder,  $\text{LiVO}_3$ , Voltammogram, Galvanostatic Charging-Discharging, Diffractogram

## 1 INTRODUCTION

The need for energy today is increasing day by day. Energy is needed to support human daily activities both as individuals and organizations. Small activities such as turning on the lights, cooking, and even transportation all require energy. Especially since the introduction of smartphones, energy seems to be inseparable from the grip. So far, the energy needs are obtained from fossil fuel sources such as oil and natural gas. However, because the use of energy using fossil fuels has a negative impact on the environment, the availability of alternative energy is very important. The provision of alternative energy cannot be separated from energy storage devices. This device for energy is called a battery. Batteries can be found everywhere around us, especially on electronic devices such as smartphones, laptops, remotes, and even children's toys. With the battery, it is

hoped that we can be free from dependence on fossil energy sources.

A battery is a device that works by converting chemical energy into electrical energy. There are two types of batteries used in everyday life, namely rechargeable batteries and non-rechargeable batteries. It turns out that rechargeable batteries are preferred because when the battery runs out we don't have to repeatedly buy new batteries and disassemble our electronic devices because of the small battery capacity. Therefore scientists are now continuing to develop rechargeable batteries with larger capacities, faster recharge times and longer discharge times. This rechargeable battery is what we know as a lithium ion battery, Lithium Ion Battery (LIB). This battery uses Lithium ions as its electrochemical propulsion. Generally, lithium ion batteries consist of four parts, including electrodes (positive electrode and negative electrode), electrolyte, separator, and container. The positive

electrode is called the cathode while the negative electrode is called the anode. When the battery is used electrons flow from the anode to the cathode. Meanwhile, when the battery is recharged, electrons flow the opposite way from the cathode to the anode

The anodes commonly used in lithium ion batteries are graphite or carbon. There have been many studies that carbon derived from plant biomass can be used as a supercapacitor. Previous research has made carbon electrodes from gelam bark powder having a capacitance of 350 mF/g (Syarif, 2013). Carbon electrodes from aquatic biomass, such as water hyacinth, have a capacitance of 93.73 mF (Rajawat, 2014), carbon from apu-apu plants has a capacitance of 401.3 mF/g (Eka Yunita, 2016).

By using the same approach as making electrodes from grasshopper carbon, this research used water spinach as the anode (negative electrode) in lithium ion batteries. As for the cathode, vanadium oxide (VO) is used. Transition metal oxides such as NiO, MnO<sub>2</sub>, TiO<sub>2</sub>, VO<sub>3</sub> are starting to be widely used as substitutes because these transition metals in the form of conductors or semiconductors exhibit active redox properties. Several studies have been conducted on the synthesis of VO<sub>3</sub>. VO<sub>3</sub> is recognized as a very attractive material because it has various crystal structures and is rich in V valence. Vanadium oxide is used as a cathode because this material is easy to manufacture, has a low voltage and has a large capacity (Pralong, 2012). The synthesis of VO<sub>3</sub> particles can increase the storage capacity and conductivity of the material. By reducing the particle size of VO<sub>3</sub>, it will increase the surface area so that the storage capacity will also be higher.

## 2. MATERIALS AND METHODS

### 2.1. Materials

The materials that were used in P.A grade were LiCl, V<sub>2</sub>O<sub>5</sub> (Merck-Germany), NaOH. The polyurethane, and melamine were purchased in local store. Water Spinach (*Ipomoea aquatica*) was our university pond.

### 2.2 Methods

#### 2.2.1 The Anode Preparation

The whole plant of water spinach was cut to obtain the leaves and into a small pieces then dried in oven at 100 °C. The dried water spinach was put into the blender and smoothed into a powder. 40 g of water spinach was mixed with 0.08 g of KOH in 100 mL aqueous solutions. The mixture was introduced into a hydrothermal reactor and heated in an oven at temperature of 200 °C and the pressure can be increases to 1.6 Mpa. After 16 hour, the

reactor was removed from the oven and cooled. The result of this process will be formed a torrefaction material. The material then fed into a microwave oven to pyrolyse. The microwave was heated with full power (1000 watts) and removed from the microwave after 25 minutes. Porous carbon was obtained from this process. The carbon was sieved with 200 mesh sieve.

#### 2.2.2 The Cathode Preparation

LiVO<sub>3</sub> powder was prepared according to the procedure shown in other paper (H.Y.Xu et.al., 2004). The materials in p.a, stoichiometrically weighted in ratio Li : V = 1 : 3. LiCl and V<sub>2</sub>O<sub>5</sub> were dissolved in 50 mL deionized water. LiCl dissolved completely and reacted with V<sub>2</sub>O<sub>5</sub>; when NaOH was slowly added to the mixture. The pH of the solution was 8. The mixture was put in a hydrothermal reactor then heated at 200 °C for 16 hour, and a grey material LiVO<sub>3</sub> was obtained.

#### 2.2.3. Battery Preparation

The anode was prepared by mixing the melamine and water spinach carbon into a paste, then the paste was coated on the surface of the Cu plate. The cathode preparation was carried out by melamine and LiVO<sub>3</sub> into a paste, then the paste was coated on the surface of the Cu plate to obtain a cathode for the battery. Melamine was used as a binder

The anode, cathode and separator were assembled into battery with the use of separator in the middle. The assembly casted in plastic pouch, pressed in laminating machine to exclude air from the pouch. The battery without electrolyte is then vacuumed and sealed airtight to obtain a battery that is ready to be filled with electrolyte. A syringe is used to insert the electrolyte liquid into the center of the assembly. The holes are covered with tape after the electrolyte liquid fills the entire body of the two electrodes. The batteries of 10, 20 and 40% of LiCl in aqueous solution were obtained for the liquid electrolytes. The preparation of gel electrolyte-based batteries was done by applying a polyvinylalcohol (PVA) gel containing 10% LiCl on the anode and cathode. The two electrodes were assembled with PVA gel in the middle and arranged together with the anode and cathode. The same procedure was applied for the batteries with 20% and 40% of electrolytes.

#### 2.2.4. The Characterisation and Performance Evaluation

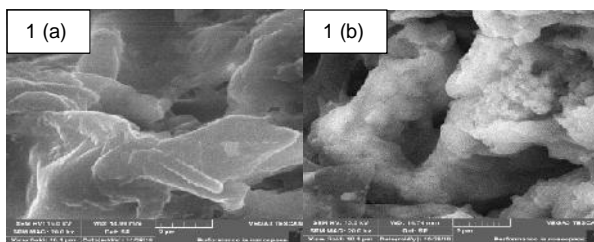
SEM images, XRD diffractograms, and FTIR spectrograms were be generated from the instrumen. The SEM images were analyzed by observing and measuring the thickness and other morphological features of water spinach carbon

using Imagej software. The XRD diffractogram was analyzed by comparing the presence of a diffraction peak at an angle of 2 theta from the measurement results with a standard database, namely ICCD or JSPDS. The FTIR spectrogram was analyzed by comparing the presence of the measured functional group absorption peaks with a standard database. In testing the battery performance, data obtained in the form of voltammograms from the results of cyclic voltammetry measurements and galvanograms from the results of measurements of galvanostatic charging discharging. The voltammogram is then used to calculate the value of energy (E) and power (P) with mathematical equations. Galvanogram is used to calculate the charging and discharging speed of the battery.

### 3. RESULTS AND DISCUSSION

#### 3.1 Morphology of The Carbon

SEM Analysis was conducted to determine the morphological structure of water spinach carbon. This test was carried out on material torrefaction (first stage results) and water spinach carbon (pyrolysis process). At 20,000x magnification in Figure (a) it can be seen that the pores formed on the surface of the torrefaction material are large and few. This is because the heating temperature is not too high, around 200 C. In the SEM test for 20,000x magnification the results of the pyrolysis process are shown in Figure (b). From the picture, it can be seen that the pores formed are many so that the process of capturing and releasing  $\text{Li}^+$  ions is more optimal.



**Figure 1.** (a) Torrefaction material and (b) Carbon of water spinach

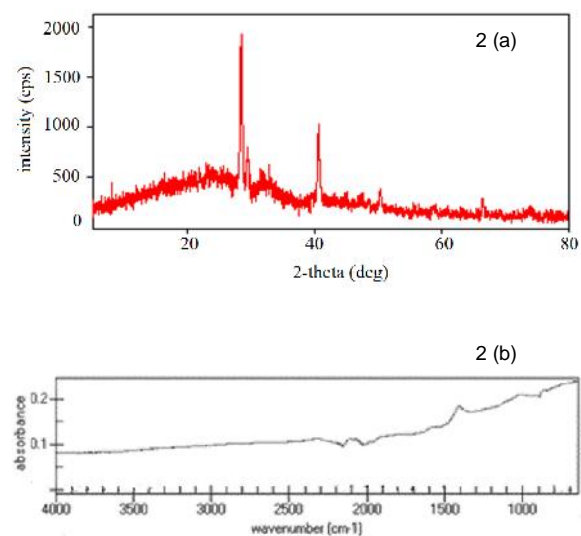
The results of EDX analysis showed that there were elements other than carbon in the water spinach carbon, oxygen, potassium, chlorine, calcium, sodium, indium, phosphorus, and sulfur. The results of the EDX analysis can be seen in Table 1.

**Table 1.** EDX Analysis of Water Spinach Carbon

Element	Symbol Element	Number Element	% Atom
Carbon	C	6	76.37
Oksigen	O	8	16.70
Potassium	K	19	2.65
Clorin	Cl	17	1.31
Indium	In	49	0.39
Sodium	Na	11	1.32
Calsium	Ca	20	0.70
Pospor	P	15	0.35
Sulfur	S	16	0.22

#### 3.2 The Cyrstallograph

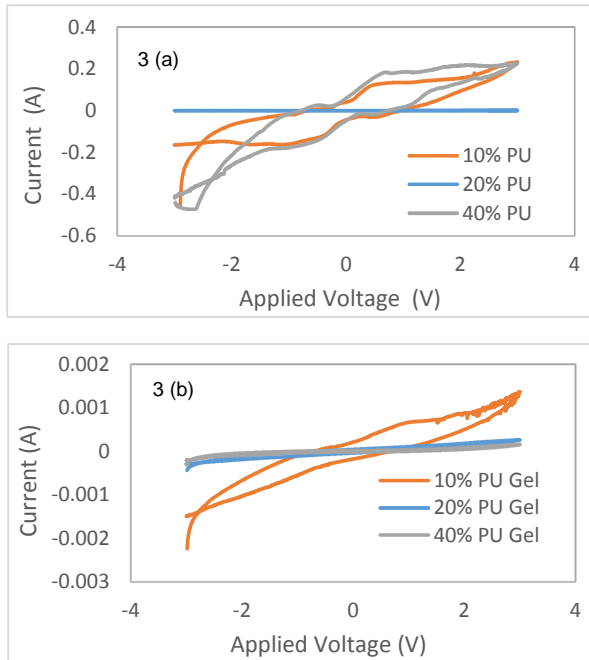
The crystallograph of carbon was characterized to detect the presence of crystalline phase and to identify the atoms in crystal in carbon. The crystalline appears as peak in range of  $2\theta$  from  $0^\circ - 80^\circ$  based on the measurement applied. The peaks indicate carbon crystalline through the two peaks in diffractogram (Figure 2),  $28.39^\circ$  and  $40.54^\circ$ . Based on the data from JCPDS, the peak formed is the phase of the KCl compound. FT-IR spectra shows 2 peaks for C – H alkane bond at  $1400\text{ cm}^{-1}$  and C C alkyne bond at  $2100\text{ cm}^{-1}$ . The high temperature provides in the pyrolysis process causes the bonds formed but in some of the functional groups to break. Carbon functional groups of water spinach in general contained C-C double bond and the aromatic groups. C – H which is used as the active group to capture and release Li ions.



**Figure 2.** (a) XRD Diffractogram and (b) FTIR spectra of water spinach carbon

### 3.3 The Electrochemical Performance

The battery was assembled with a water spinach carbon anode unit, vanadium oxide ( $\text{LiVO}_3$ ) cathode and lithium salt ( $\text{LiCl}$ ) electrolyte in order to make performance analysis. The cyclic voltammetry (CV) were done in -3 to 3 volt of potential windows and  $25 \text{ mVs}^{-1}$  of scan rate.

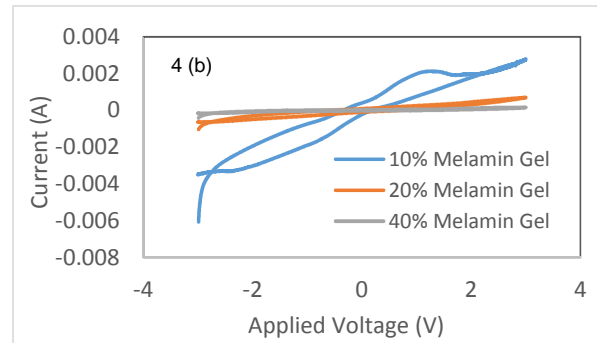
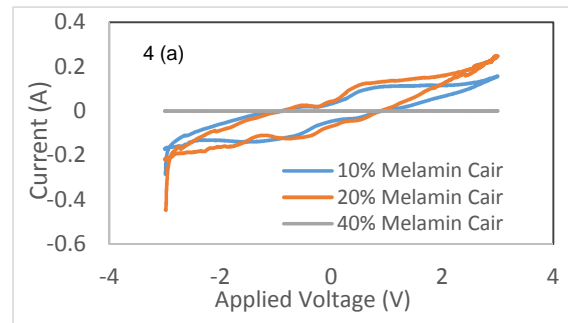


**Figure 3.** Voltammogram of  $\text{LiVO}_3$  Battery with PU Binder and electrolyte media (a) liquid and (b) gel

Battery electrolytes were made to vary, 10%, 20%, and 40% of  $\text{LiCl}$ . The electrolyte phase is also made varied, among others,  $\text{LiCl}$  gel and  $\text{LiCl}$  solution (liquid). The binders used are also varied, namely polyurethane (PU) and melamine.

Figure 3. shows the voltammogram of a lithium vanadium ion battery with a PU (*polyurethane*) binder. Based on figure (a) the largest measured current is in the liquid electrolyte phase, which is 0.11 A in 10%  $\text{LiCl}$  electrolyte,  $1.4 \times 10^{-4}$  A in 20%  $\text{LiCl}$  electrolyte, 0.22 A in 40% electrolyte  $\text{LiCl}$ . While in the PU binder with the gel electrolyte phase in Figure (b), the current the largest measured is 0.001 A in 10%  $\text{LiCl}$  electrolyte,  $2.3 \times 10^{-4}$  A, and  $1.6 \times 10^{-4}$  A.

The highest current value is when the battery uses a liquid electrolyte with a concentration of electrolyte 40% which is equal to 0.22 A. Due to the ions movement in the liquid electrolyte that move freely compare to the gel electrolyte. This provides the electric current reading greater.



**Figure 4.** Voltammogram of  $\text{LiVO}_3$  Battery with Melamine Binder and electrolyte media (a) liquid and (b) gel

Based on Figure 4. the largest rated current reading on the potentiostat is 0.16 A in a 10%  $\text{LiCl}$  electrolyte, 0.22 A in a 20%  $\text{LiCl}$  electrolyte, and  $2.1 \times 10^{-4}$  A in a 40%  $\text{LiCl}$  electrolyte. Voltammogram of the battery with a melamine gel binder (Figure 4(b)) show that the current measured is  $2.1 \times 10^{-3}$  A in 10%  $\text{LiCl}$  electrolyte,  $6.7 \times 10^{-4}$  A in 20%  $\text{LiCl}$  electrolyte, and  $1.5 \times 10^{-4}$  A in 40%  $\text{LiCl}$  electrolyte. In the melamine binder, the largest current is in the 20%  $\text{LiCl}$  liquid electrolyte, which is 0.22 A.

The electric current from the battery with melamine binder of electrode and in the liquid electrolyte is greater than the electric current in the gel electrolyte. This happens because in liquid electrolytes, the electrons move more freely than gel electrolytes, resulting in a larger electric current.

The current measured in the potentiostat depends on the movement of electrons and ions in the electrolyte. The interaction between the ions and the electrolyte must be appropriate so that the electric charge between the ions and the electrolyte can move smoothly. Electrolyte concentration that is too high can cause interference with ion adsorption on the electrode surface. If the electrolyte concentration is too low, the ionic charge transferred slightly low, provide low electric current in turn.

The cyclic voltammetry measurements provide values for calculating the power, energy, and capacity values which can be seen in Table 2.

**Table 2.** The Performances of The Batteries

Battery Variation	Power (W)	Energy (W.h)	Capacitance (F)
Liquid PU 40%	0.536	0.018	0.894
Gel PU 40%	0.002	$6,90 \times 10^{-6}$	$3,43 \times 10^{-4}$

The battery with liquid electrolyte has greater power, energy, and capacity values compared to the gel electrolytes (Table 2). Li ions move more easily liquid electrolytes because the distance between the particles in the liquid electrolyte is not as dense as that of the gel electrolyte. Due to Li ions in the liquid electrolyte can move to the cathode and anode more quickly and the reaction takes place maximally.

Galvanostatic measurements of battery provide information about the cycle stability and charging – discharging rate. The cycle that has the lowest voltage shift compared to the other cycles. The calculation of the charging – discharging slope of the battery was based on the curve shown in Table 3.

**Table 3.** The slope of charging and discharging

The Battery Variation	Slope Charging	Slope Discharging
Liquid PU 40%	0.0044	-0.0039
Gel PU 40%	0.3548	-0.4148

Based on the calculation results, batteries with liquid electrolyte media using either a melamine binder or a PU binder have a lower battery discharge slope value than the battery charging slope value. This shows that the battery discharge speed is longer than the battery charging speed. In other words, batteries with liquid electrolyte media can be used longer than batteries with gel electrolyte media. This is because in liquid electrolyte media, Li ions can move more freely than batteries with gel electrolyte. In batteries with gel electrolyte media the movement of Li ions will be hampered by the presence of polyvinylalcohol (PVA) so that the capture and release of Li is not optimal. The battery with the lowest slope value or the longer usage is the battery with PU binder with 40% liquid electrolyte media. The battery with the highest slope value or faster on the usage of melamine binder and 40% LiCl of gel electrolyte.

#### 4. CONCLUSION

Material characterization reveal that the carbon has crystalline phase, conductivity and pores which therefore carbon has the capability to be used as anode precursor. The evaluation of battery performance showed that the highest current value was found in battery with 40% LiCl of liquid electrolyte and polyurethane binder, that is 0.22 A.

The highest power  $5.36 \times 10^{-1}$  W, energy  $1.80 \times 10^{-2}$  Wh, and capacity  $8.94 \times 10^{-1}$  F was found in battery with 40% LiCl of liquid electrolyte with binder PU.. The lowest battery discharge slope 0.0039 was found in 40% LiCl of liquid electrolyte with PU binder. These findings provides an alternative to the use of materials in Lithium ion batteries without compromising the performance of their application.

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