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The effect of potassium iodide (KI) addition to aqueous-based electrolyte (sulfuric acid/H_2SO_4) for increase the performance of supercapacitor cells

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ABSTRACT

Potassium iodide (KI) has been added to aqueous-based electrolyte (sulfuric acid/H_2SO_4) has succeeded in showing the pseudo-capacitance properties that can increase the specific capacitance of supercapacitor cells. The carbon electrodes for supercapacitor cell made from bamboo stems. As supporting data, surface morphology and crystallinity of carbon electrodes have also been analyzed by using scanning electron microscopy (SEM) and X-ray diffraction (XRD) characterization. Whereas in determining specific capacitance of supercapacitor cells, it was carried out using the cyclic voltammetry (CV) method. The CV test results present the addition of KI 0.05 M in 1 M H_2SO_4 solution has increased the specific capacitance from 159F g^{-1} to 200F g^{-1}.

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1. Introduction

Supercapacitors are one of the energy storage devices that support the effectiveness of alternative energy today. Supercapacitors have advantages compared to other storage energy such as low-cost production, high security, long life time, and relatively fast charge/discharge times [1]. The component of the supercapacitor cell affects the energy and power densities of the electrode. Electrodes can be made from activated carbon because it has advantages including high conductivity, large surface area and high energy storage capability [2]. Activated carbon can be produced from biomass materials such as cotton [3] coconut, wood and bamboo [4]. Biomass materials are popular carbon sources because it is cheap, easy to production and has abundant availability in nature. In addition to electrodes, electrolytes also affect the performance of supercapacitor cells. Electrolytes must be able to produce a high charge and be able to enter the pores contained in the electrode to be good in increasing specific capacitance. H2SO4 is one of the electrolytes which is good for supercapacitor cell applications, it has a dissociation potential of 1.23 V, conductivity of $\pm 8/\Omega$, can be used at high temperatures of 150 °C and the ion diameter size of 0.26 nm. The ion size of the H_2SO_4 is smaller than other aqueous electrolytes such as KOH and KNO_3. The small ion size of H_2SO_4 allows the number of ions to enter the electrode pores. Electrolytes with the addition of addictive materials have been used to increase the value of specific capacitance up to three times [5]. One of the addictive materials that can be used as an electrolyte is Potassium iodide (KI). KI is chosen for its relatively cheap price curry, wide availability and good chemical stability [6]. This study presents the effect of H_2SO_4 and KI + H_2SO_4 electrolytes on the electrochemical properties of supercapacitor cells. The carbon materials derived from bamboo stems are chosen as the electrode because possess excellent performance of the larger surface area and higher total pore volume, which provide reaction place and transport channel for the ions in the electrolyte. Furthermore, one stage integrated pyrolysis both carbonization and physical activation and $ZnCl_2$ impregnation are selected to bamboo stems into activated carbon electrode. Based on this result, the addition of KI 0.05 M in 1 M H_2SO_4 solution has been potential to enhance the performance of supercapacitor electrode.

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2. Materials and methods

2.1. Preparation of activated carbon electrodes

Activated carbon made from bamboo stem collected in the Riau province. The preparation process activated carbon made from bamboo stem carried out by similar method that has been previous reported [7–10]. The carbon electrode was synthesized by the direct carbonization in N2 gas atmosphere at a temperature of 900 °C for 2.5 h. The electrolyte provided were 1 M H_2SO_4 and 1 M H_2SO_4 + 0.05 M KI. Mixed electrolytes were prepared by adding 0.05 M KI solution into 1 M H_2SO_4 solution under magnetic stirring at a temperature of 80C. Based on electrolyte variations, the samples were labeled KF and KFI for activated carbon with H_2SO_4 electrolytes and activated carbon with H_2SO_4 + KI electrolytes, respectively. In detail, the preparation of activated carbon electrodes shown in Fig. 1.

2.2. Characterization of carbon electrode

The electrochemical properties of various electrolytes were reviewed using the Cyclic Voltammetry (CV) method. The instrument used is the Physics CV UR Rad-Er 5481 scan rate of 1 mV s^{-1} and a potential of 1.0 V. The physical properties of activated carbon electrodes also analyzed to support the electrochemical analysis. Several physical properties such as density, microstructure, surface morphology, and chemical content were characterized by using the X-Ray Diffraction, Scanning electron microscopy and Energy Dispersive X-ray.

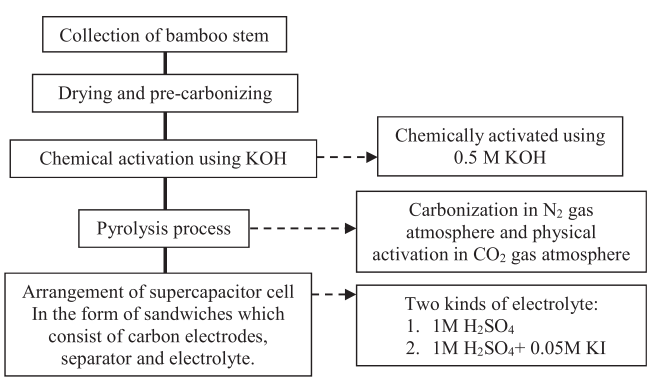

Fig. 1. Schematic diagram for the preparation of activated carbon.

3. Result and discussion

3.1. Physical properties analysis

Activated carbon electrodes before and after the carbonization process measured the density in all samples. In Fig. 2(a) shows the average density of the activated carbon electrode before the carbonization process as high as 1.1644 g m^{-3} is greater than after carbonization process of 0.9234 g m^{-3} it is caused in the carbonization process occurs evaporation of other elements than carbon in samples such as hydrogen, oxygen and other impurities [11], evaporation in the sample results pores so it can affect the mass, thickness and diameter where this affects the density in the sample. The microstructure of the carbon electrode is characterized using XRD which shown in Fig. 2(b). Fig. 2(b) shows a wide peak at 2θ angle in range of 24° and 44°, indicating the sample has an amorphous structure. Sharp peaks also seen in Fig. 2(b) indicate the presence of silica (SiO_2) elements that often appear in biomass materials [12].

The surface morphology of activated carbon electrodes is characterized by using SEM method with magnification of 5000x which shown in Fig. 3(a), Fig. 3(a) shows pores formation with average diameter size of 0.811 μm. Pore diameter is measured on the surface of the electrode but needs another method such as TEM to determine the inner pore diameter. The carbonization process increase pore size due to the breakdown of carbon particles forming new particles and expanding existing pores [13,14]. Fig. 3(b) shows the SEM micrograph with a magnification of 40000x. Its exhibit fibres with average diameter of 72.65 nm, indicates the sample has a homogeneous pore area so ion will be easy to diffuse and impact the specific capacitance of the supercapacitor cell. The chemical content analysis of the samples possessed by using energy dispersive spectroscopy (EDS) method. Fig. 3(c) shows the highest peak is found by the carbon element of 93.15%, furthermore there are other elements such as oxygen, silica, potassium and calcium. The appearance of oxygen is due to the carbonization process. Silica elements appear because natural content element in biomass [12], potassium elements arise due to KOH activators during the chemical activation process while calcium elements arise due to natural content in bamboo stem.

3.2. The electrochemical properties analysis

The electrochemical behaviors of KF and KFI samples are initially studied using a two-electrode system, and the CV results are exhibited in Fig. 4. In details, Fig. 4 shows the CV curves of the KF sample with fairly rectangular shape in 1 M H_2SO_4 electrolyte at 1 mv s^{-1} scan rate, indicating almost ideal feature of electric double layer capacitances (EDLCs) [15]. The large rectangle size

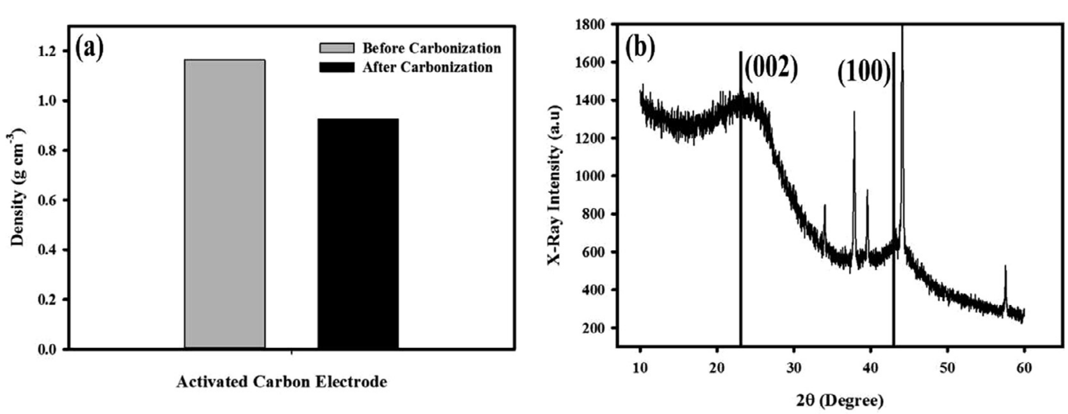

Fig. 2. (a) Density before and after carbonization (b) XRD pattern for KF.

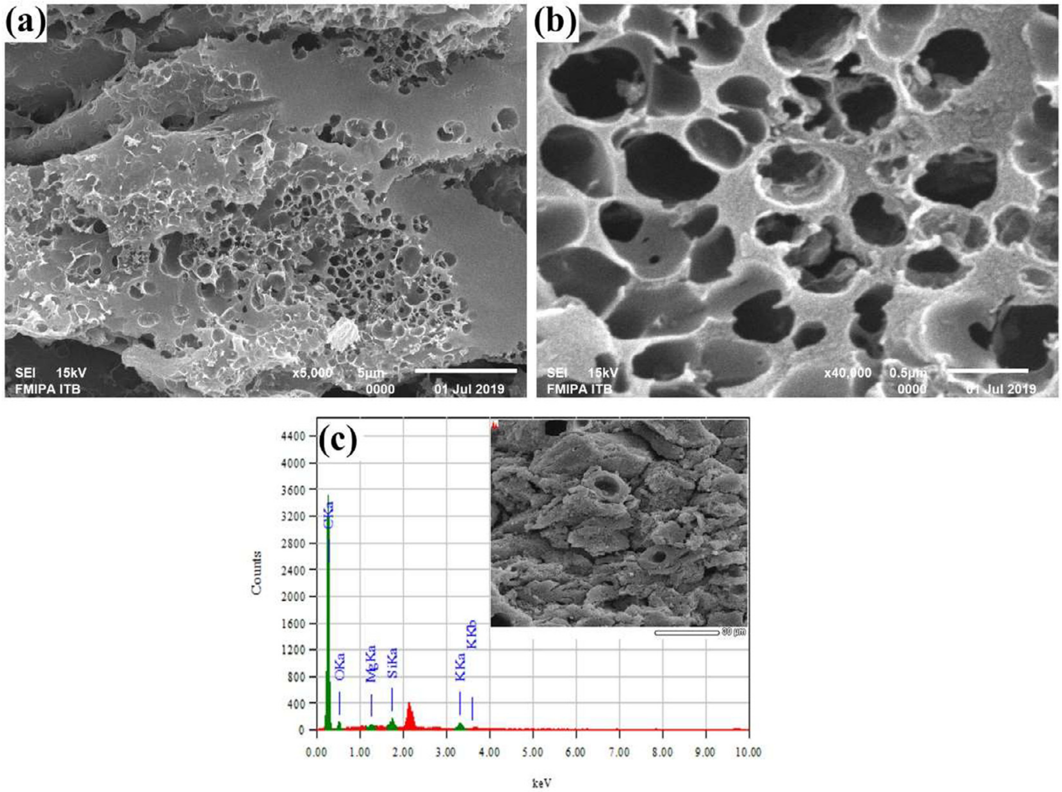

Fig. 3. (a) SEM macrograph of carbon electrode with magnification of 5000x; (b) SEM macrograph of carbon electrode with magnification of 40000x; (c) EDX pattern for carbon electrode of bamboo stem.

indicates the high specific capacitance. KI as a redox additive was tested with 1 M H_2SO_4 exhibit oxidation/reduction peaks in the KFI sample while no peak exists in the KF sample. This added redox peaks provide extra pseudo-capacitances for supercapacitors. KI solutions in electrolytes add to the pseudo-capacitance properties cause H_2SO_4 to synergize in redox reactions [5]. Redox reactions that occur significantly increase specific capacitance, i.e. from 159F g^{-1} for KF samples up to 200F g^{-1} for KFI samples. Based on the results has been analyzed, KI + H_2SO_4 electrolytes have been increased specific capacitance. This work is similar to several other studies which also discuss the effect of KI solution to electrolytes for the performance of supercapacitors [5,6].

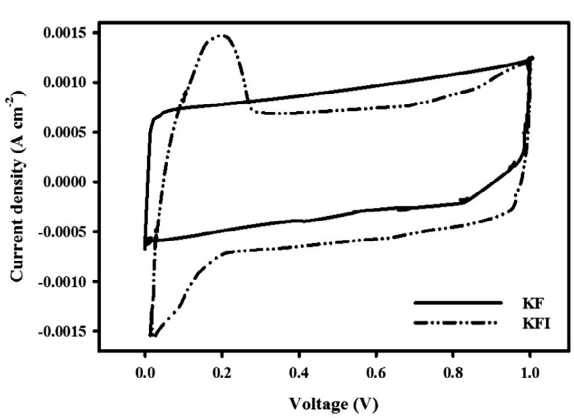

Fig. 4. Cyclic Voltammogram curve of KF and KFI electrodes.

4. Conclusion

The supercapacitor cell has been prepared from bamboo stem based activated carbon in H_2SO_4 and H_2SO_4 + KI as aqueous electrolyte. There exists synergistic effect of 0.05 M KI in 1 M H_2SO_4 electrolyte, which is due to the simultaneous redox reaction of KI solution. This added redox provides extra pseudo-capacitances for supercapacitors which increase specific capacitance from 159F g^{-1} to 200F g^{-1}. The other hands, physical properties of bamboo based activated carbon electrode support the electrochemical properties of H_2SO_4 + KI as aqueous electrolyte.

CRediT authorship contribution statement

E. Taer: Conceptualization, Methodology, Software. **A. Putri:** Writing - original draft. **R. Farma:** Formal analysis, Data curation. **Awitdrus:** Validation, Visualization. **R. Taslim:** Visualization, Investigation. **Apriwandi:** Writing - review & editing. **Agustino:** Project administration. **D.A. Yusra:** Investigation, Methodology.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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