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Study of Dielectric and Adsorption Properties of Activated Carbon Prepared from Water Hyacinth using KOH as an Activating Agent

Mochammad Ghiffari[1,a], Wenny Maulina[1], and Agung Tjahjo Nugroho[1]

[2]Departmen of Physics, Faculty of Mathematics and Natural Sciences, Universitas Jember, Jember 68121, East Java, Indonesia

[a]arifary430@gmail.com

Abstract. Activated carbon can be produced from the combustion of a materials containing carbon that has been activated using activator substances. In this paper, potassium hydroxide (KOH) was selected as an activating agent. The influence of KOH concentration was investigated to determine the dielectric and adsorption properties of activated carbon derived from water hyacinth. Drying water hyacinth was carbonize in the furnace at a temperature of 400°C followed by chemical activation with variation concentration of KOH solution that used are 25%, 30%, and 35% (w/v) respectively. The results show that the best activated carbon derived from water hyacinth was obtained using 35% (w/v) KOH solution as an activating agent with the dielectric constant is 4.04 while iodine number of 514.6 mg/g.

Keywords: Water Hyacinth, Activated Carbon, KOH, Dielectric Constant, Iodine Number

Introduction

Indonesia is a country that has high biodiversity, but all of them have not been fully utilized. One of the biodiversity that is easily found is water hyacinth. Water hyacinth (*Eichhornia crassipes*), the aquatic biomass, has attracted significant attention due to its extremely rapid growth, presenting serious challenges in navigation, irrigation and power generation [1-2]. Water hyacinth has many benefits, one of which can be made into fertilizer for the growth of fluted pumpkin (Telfairia occidentalis) [3], the diets of sheep [4], biodegradable board [5], biomass briquette [6], and activated carbon for phosphate removal from wastewater [7]. Furthermore, water hyacinth is critical to be studied for its possibility as an alternative energy source [8]. For example, water hyacinth has been demonstrated to be useful to develop supercapasitors, for production ethanol and to improve the immune resistance of plants and animals [9].

Carbon materials are a black residue containing impure carbon produced from the process of burning materials containing carbon elements. Carbon materials can be produced from materials containing carbon by heating at high temperatures [10]. Activated carbon is a carbonaceous solid derived from coal or biomass via thermal or thermochemical processes [2]. In general, activated carbon can be divided into physical and chemical activation. Physical activation is a process of breaking carbon chains from organic compounds with the help of heat at temperatures of 800ºC to 900ºC [11]. Meanwhile, chemical activation is soaking charcoal with chemical compounds before heating [12]. The chemicals that are usually used for activation are $CaCl_2$, $MnCl_2$, KOH, $Ca(OH)_2$, $ZnCl_2$, $NaOH$, H_3PO_4, H_2SO_4, K_2CO_3, Na_2CO_3 [13]. Based on the fact that the activating agents potassium hydroxide (KOH) performed much better than the other activating agent in terms of its ability to produce very high surface area carbon. KOH was found to generate carbon with the highest porosity and surface area [14]. A number of studies

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have been carried out to using KOH as an activating agent. Hwa-Young et al. synthesis of activated carbon from paper mill sludge by KOH-activation [15]. Yang et al. studied on the application of KOH to produce activated carbon to realize the utilization of distiller's grains [16]. Pagketanang et al. investigated microporous activated carbon from KOH-activation of rubber seed-shells for application in capacitor electrode [17]. Jin-Young and Young-Seak measure electrochemical properties of KOH-activated lyocell-based carbon fibers for EDLCs [18].

The number of pores and large surface area correlate with the adsorption power of activated carbon [12]. In this study, iodine number was carried out to determine the adsorption capacity of activated carbon prepared from water hyacinth at various concentrations of KOH as an activating agent. Aside from iodine number, measurement of electrical properties of activated carbon was also carried out. The use of activated carbon as a raw material for electronic devices, such as batteries, has been widely carried out.

Theoretical Background

The use of carbon materials have been used for many applications, such as batteries, supercapacitors, gas sensors and dye-sensitized solar cells [19]. Over the years, the furnace has been used as a common heating method to manufacture carbon. In a furnace, heat is transferred through conduction and convection. The outer surface of the sample is in contact with the generated heat, which slowly diffuses inwards as a result of the thermal gradient between the surface and the core of the material's particles [20].

Activated carbon refers to a wide range of carbonized materials of high degree of porosity and high surface area. Carbon structures contain the main functional groups such as carboxyl, carbonyl, phenol, lactone and quinone that are responsible for adsorbing contaminants. Oxygen, hydrogen, sulphur and nitrogen are also present in the form of functional groups or chemical atoms in the activated carbon structure. The unique adsorption properties depend on the existing functional groups of activated carbon, which are derived mainly from activation processes, precursors and thermal purification [21].

Potassium hydroxide (KOH) has been widely used as an activating agent in activated carbon preparation. During the activation process, the following reaction take place [20,22]:

$$C + 2KOH \rightarrow 2K + H_2 + CO_2 \tag{1}$$

$$C + 2KOH \rightarrow 2K + H_2O + CO \tag{2}$$

$$CO_2 + 2KOH \rightarrow K_2CO_3 + H_2O \tag{3}$$

Both mesopores and micropores are formed as a result of the intercalation of potassium into the carbon network during the activation. Besides, there is also a possibility for a secondary reaction to occur as follows:

$$H_2O + C + 2KOH \rightarrow K_2CO_3 + H_2 \tag{4}$$

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The dielectric properties of the materials are very important in evaluating the penetration of energy that can be achieved [23]. The dielectric constant can be determined from the capacitance measurement, as follow [24]:

$$C = \frac{\kappa \varepsilon_0 A}{d} \tag{5}$$

Where "C" is capacitance (F), "κ" is the dielectric constant, "ε_0" is permittivity of the vacuum (8.85×10^{-12} C^2/Nm^2), "A" is the area of the plates (m^2), and "d" is the plate separation (m). The product $\kappa\varepsilon_0$ is called the permittivity of the medium and is denoted by ε,

$$\varepsilon = \kappa \varepsilon_0 \tag{6}$$

For vacuum $\kappa = 1$ and $\varepsilon = \varepsilon_0$. The dimensionless ratio:

$$\kappa = \frac{\varepsilon}{\varepsilon_0} \tag{7}$$

Is called the dielectric constant of the substance. As remarked before, the dielectric constant can be calculated as bellow

$$\kappa = \frac{C}{C_0} \tag{8}$$

Thus, the dielectric constant of a substance is the factor (>1) by which the capacitance increases from its vacuum value, when the dielectric is inserted fully between the plates of a capacitor.

Adsorption capacity of activated carbon mainly depends on its porosity and surface area. Higher iodine numbers reflect better development of the microporous structure and higher adsorption abilities for low-molar-mass solutes [25]. The iodine sorption value (ISV) was calculated according to the Equation (6) bellow [26]:

$$ISV = A \frac{\frac{B \times N(Na_2S_2O_3)}{N(iodin)} \times 126{,}93 \times fp}{\alpha} \tag{9}$$

where "ISV" is iodine sorption value (mg/g), "A" is volume of iodine solution (ml), "B" is volume of sodium thiosulfate ($Na_2S_2O_3$) used (ml) "N($Na_2S_2O_3$)" is concentration of sodium thiosulfate (N), "N(iodine)" is concentration of iodine (N), "α" is mass of activated carbon (g) and "fp" is dilution factor.

Materials and Methods

Preparation of water hyacinth activated carbon

In this study, the stems of water hyacinth were used for the preparation of activated carbon. The stems of water hyacinth were cleaned, chopped into pieces and dried using oven for 24 h at 105°C until they become crispy. Then the dried stems of water hyacinth was grinded until it

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becomes powder. This powdered was heated up to 400°C in the furnace about 1 h to make relative charcoal. The water hyacinth charcoal was sieved to a mesh size of 200.

To prepare activated carbon of water hyacinth, the charcoal was chemically activated using potassium hydroxide (KOH) as activating agent with concentration of 25%, 30%, and 35% (b/v), respectively. The process continued by heating and stirring using magnetic stirrer hotplate at 80°C for 4 h. The sample was filtrate and washed with chemical of 2 M HCl followed by distilled water to make the sample neutral and put in the oven again for 2 h at 100°C. After this process, the activated carbon derived from water hyacinth ready to use in measurement.

Dielectric properties measurement

Dielectric properties were measured using LCR meter Lutron 9183. The measurement of activated carbon derived from water hyacinth was carried out using a parallel plates capacitor. The activated carbon was poured in 31 mm × 31 mm × 4 mm rectangular planner moulds. The measurement procedure which is done by contacting the probe to a flat surface of sample, as shown in Figure 1. The experiment was measured capacitance at a frequency of 10 kHz. The dielectric constant was found by using equation (8). The measurement was repeated to all different concentration of potassium hydroxide (KOH) activator. Since the experimental variables are more in number it was planned to check the result and data through analysis of variance (ANOVA). ANOVA was used to estimate the statistical parameters.

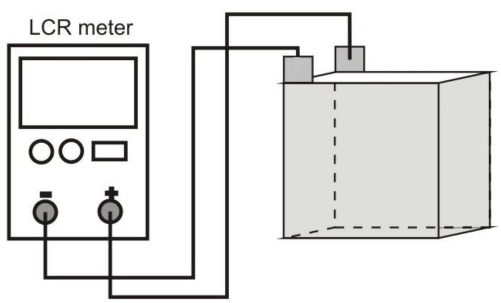

Figure 1. Set-up of dielectric properties measurement

Determination of the iodine sorption value (ISV)

A 5 g activated carbon derived from water hyacinth was mixture with a volume of 100 mL concentrated iodine solution (1 N). The mixture was allowed to stand for 15 minutes in order to reach sorption equilibrium between activated carbon and concentrated iodine solution. The aliquot amount of sample and iodine solution were titrated with 0.1 N sodium thiosulfate solution. The ISV was calculated according to the Equation (9). The measurement were conducted for each type of activated carbon.

Results and Discussion

Dielectric Properties

Dielectric materials are characterized by their dielectric properties. Dielectric properties determine the ability of the material to absorb energy. The dielectric constant defines a measure of how much energy from an external electric field can be stored within a material through polarization mechanism [27-28]. The results in activated carbon electromagnetic constant are

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shown as Figure 2. From Figure 2 can be seen the dielectric constant of the activated carbon increased with increasing concentration of activating agent. The dielectric constant of the activated carbon derived from water hyacinth using concentration of KOH (25 wt%, 30 wt% and 35 wt%) are 2.78 ± 0.18, 2.82 ± 0.21, and 4.04 ± 0.29, respectively. The increase in the concentration of KOH causes the dielectric constant value will also increase. An increase the magnitude of dielectric constant is thought to be due to an increase in the surface area of activated carbon. The use of KOH as activating agent was found to generate carbon with the highest porosity and surface area [14]. These results were in agreement with those of Yuningsih et al. in the activation of corn cobs and coconut shell carbon with KOH where surface area or pores volume increased with increase in KOH concentration [29]; Tetra et al. who observed that the ability of activated carbon to store an electrical charge will increase as the surface area of activated carbon increases [30].

The experimental data and analysis were checked by one-way ANOVA to determine the effect of KOH concentration on the dielectric properties of activated carbon derived from water hyacinth. Based on the one-way ANOVA test, the results obtained Pvalue (Sig) <0.05, which means Ho is rejected, meaning that there is an effect of varying the concentration of KOH activator in the process of synthesizing activated carbon derived from water hyacinth to the value of the dielectric constant.

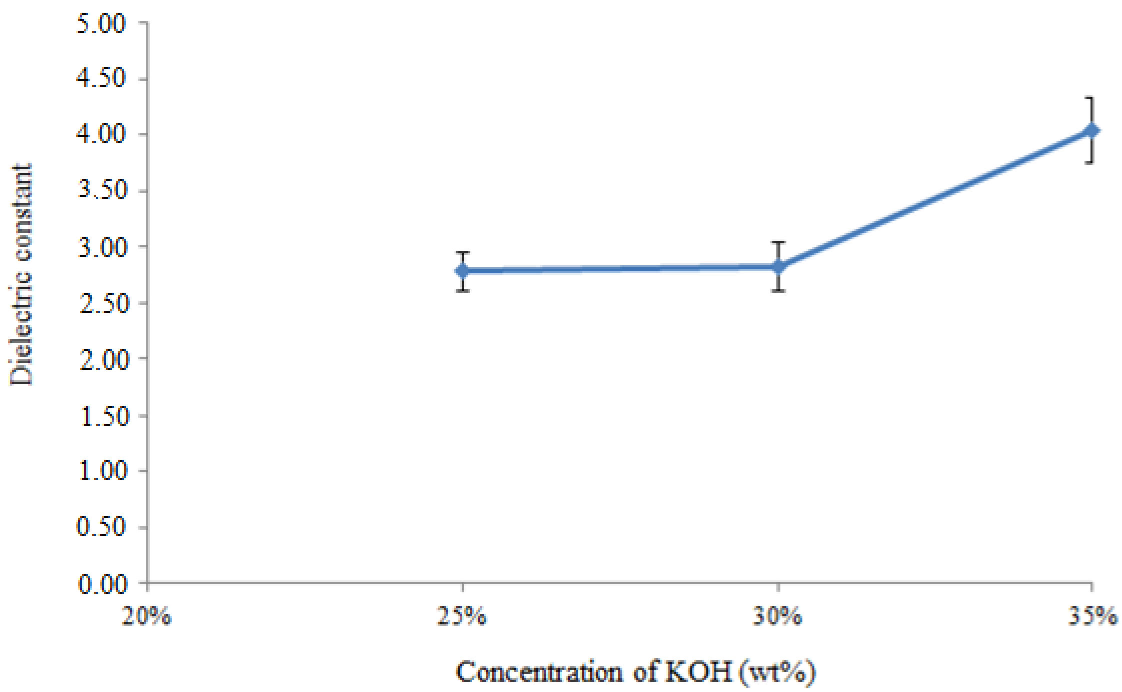

Figure 2. The dielectric constant of activated carbon derived from water hyacinth using KOH as activating agent

Iodine Sorption Value (ISV)
The effects of varying the concentrations of the activating agent (KOH) on the iodine number of the chemically activated carbon derived from water hyacinth are shown in Figure 3. Figure 3 showed that the iodine number increased with increasing concentration of activator. The results

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of the iodine number of activated carbon derived from water hyacinth with a concentration of 35wt% KOH shows the highest iodine sorption value of 514.6 mg/g, while the concentration of 30wt% KOH was 477.8 mg/g and the lowest iodine number was with a concentration of 25wt% KOH of 409.5 mg/g.

The increase in the iodine number was due to increase in pore formation and hence adsorptive capacity of the activated carbon as impregnation increased. The iodine number is defined as the milligrams of iodine adsorbed by one gram of carbon when the iodine residual concentration of the filtrate is 0.02N (0.01 mol/L) according to ASTM D4607 standard, which is based on a three-point isotherm. Hence it is a measure of the iodine adsorbed in the pores of the activated carbon and an indication of the pore volume available in the activated carbon. Therefore, the carbon should be activated at concentration that gives the highest iodine value [31].

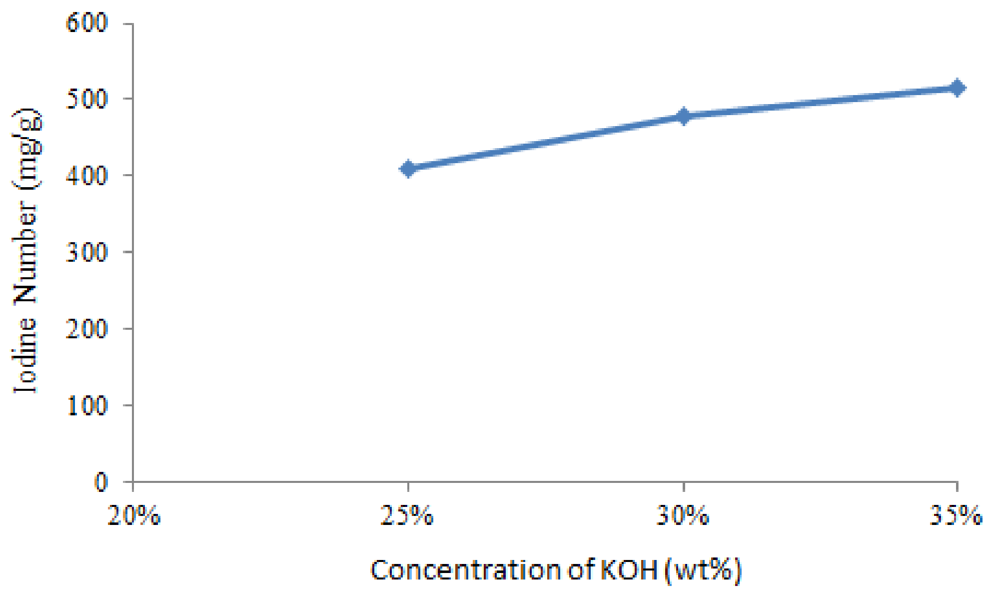

Figure 3. Effect of concentration of KOH as activating agent on iodine number of activated carbon derived from water hyacinth

Conclusions

From this experiment, activated carbon derived from water hyacinth in various concentration KOH activator in term of the dielectric properties and iodine sorption value have been investigated. It has been seen that the increase concentration of KOH in the process of synthesizing activated carbon causes increasing the dielectric constant and iodine number. In addition, optimum activated carbon derived from water hyacinth was obtained when the value of the dielectric constant was minimum and the value of iodine number was maximum. The dielectric constant minimum when concentration of 25wt% KOH was 2.78 ± 0.18, meanwhile iodine number maximum when concentration of 35wt% KOH was 514.6 mg/g. Based on the results obtained, it is known that the dielectric properties and iodine sorption value from activated carbon can be used according to theirs application later.

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