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MEASUREMENT OF ELECTRICAL PERMEABILITY AND CONDUCTIVITY OF COCOA POD HUSK-BASED ACTIVATED CARBON AS AN ALTERNATIVE BATTERY MIXTURE MATERIAL

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ABSTRACT *(10pt, Bold)*
In the development of various contemporary technological applications, the electrical properties of materials are crucial. This study analyzed activated carbon made from cocoa pod husk (PCC) for its electrical permittivity and conductivity. Parallel plates measuring 8 cm x 8 cm with a distance between plates of 0.5 cm were used for both measurements. The PCC activated carbon served as a dielectric between the plates. To measure the conductivity of the material, a DC voltage source was connected to the material at 0.5 volt intervals within the range of 3 to 5 volts. The electrical conductivity obtained was 5.5 × 10–5 S/m, indicating that the PCC activated carbon is a semiconductor. In addition, electrical permittivity measurements were also carried out using an AC voltage source with a frequency range of 10,000 Hz to 100,000 Hz. The results showed that increasing frequency was negatively correlated with decreasing permittivity values. The permittivity value reached 65.52 at low frequency (10,000 Hz), but decreased to 16.15 at high frequency (100,000 Hz). This decrease indicates the high frequency dielectric dispersion of KBK activated carbon.Keywords: Paper Format, JMT, jurnal

Keywords : *Waste, Cocoa, Activated Carbon, Permittivity, Electrical Conductivity*

1. Introduction

The production of cocoa pod husk waste (CPHW) has increased as a result of the growing cocoa plantation industry in Indonesia [1]. This waste is composed of lignin, cellulose, and hemicellulose and can be generated in large quantities during the chocolate manufacturing process [2]. Due to its potential applications in various fields, such as electrode materials for supercapacitors and adsorbents, activated carbon derived from CPHW has become the focus of this study.

Advancements in material physics, particularly in electrical properties, have expanded the use of materials as conductors, dielectrics, or semiconductors [3]. Modern technology relies heavily on dielectrics, which possess low electrical conductivity, in the production of capacitors, such as parallel-plate capacitors. As shown in previous studies [4,5], CPHW-based activated carbon exhibits significant capacitance and a promising response to variations in temperature and frequency. However, comparisons with prior research reveal differences in the obtained findings. This highlights the importance of further investigation into the electrical characteristics of CPHW-based activated carbon. The objective of this study is to examine the electrical conductivity and permittivity of CPHW-based activated carbon at various frequencies. It is expected that this research will provide a deeper understanding of the potential applications of CPHW-based activated carbon in electrical technology and contribute to the development of more efficient and sustainable technologies.

2. Research Methods

Tools and Materials

The tools and materials used in this study included a furnace, hot plate, grinder/pestle, 200-mesh sieve, beaker glass, porcelain crucible, generator, single-core wire, plain PCB board, magnetic stirrer, copper, PCB cutter, transparent glass, and adhesive glue. The purified water and chemical reagents used in this experiment consisted of distilled water (aquadest), potassium hydroxide (KOH), potassium chloride (KCl), filter paper, and cocoa pod husk (CPHW) as the primary raw material.

Material Preparation

The cocoa pod husk (CPHW) waste, obtained from a cocoa plantation in Pariaman, was prepared through several stages. First, it was thoroughly washed with clean water, allowed to dry, and then cut into small pieces and thin slices. The initial mass of the CPHW was measured using a digital balance. Subsequently, the CPHW was sun-dried to reduce its moisture content. To further remove residual water, a dehydration process was carried out for fourteen days to obtain an optimal result. After the dehydration process was completed, the CPHW was weighed again to determine its final mass. For the carbonization stage, the dehydrated CPHW was converted into charcoal using a furnace. The clean and dry CPHW was placed in an aluminum tray and heated in the furnace at 400°C for one hour. After the carbonization process was completed, the material was left in an oven for 24 hours to ensure optimal charring. The charcoal, after being conditioned for 24 hours, was then ground and sieved using a 200-mesh sieve. This grinding process aimed to produce a fine powder to facilitate the subsequent mixing of the activated carbon with potassium hydroxide (KOH) [5].

In the activation process of the carbon, the ground and sieved cocoa pod husk (CPHW) charcoal (200-mesh) was activated using a potassium hydroxide (KOH) solution with a concentration of 0.4 M. The mass ratio between the activator and the CPHW charcoal was 2:1, with a total sample mass of 50 grams. The soaking process was carried out in a beaker glass sealed with plastic wrapping to ensure that the activator thoroughly penetrated and interacted with the carbon material. The purpose of this step was to allow the activating agent to break the carbon chains of the organic compounds as effectively as possible. To ensure optimal activation, the mixture was left to soak for 24 hours. After the activation period, the carbon was washed with distilled water (aquadest) until its pH reached a neutral level. The neutralized carbon was then dried in a furnace at 105°C for 3 hours to remove residual moisture remaining after the washing process. This drying step was crucial to minimize water content in the CPHW activated carbon. Subsequently, physical activation was performed by reheating the chemically activated carbon in the furnace for one hour. Afterward, 1 gram of potassium chloride (KCl) was dissolved in 10 milliliters of distilled water and stirred using a magnetic stirrer for fifteen minutes. Then, 10 grams of the activated carbon were added to the KCl solution and mixed thoroughly until a homogeneous mixture was obtained [5].

Capacitor Fabrication

He capacitor plates used in this study were self-assembled components. Each plate was made of copper with dimensions of 8 cm × 8 cm, and the distance between the two plates was maintained at 0.5 cm.

Data Collection

The process of data collection and testing aimed to determine the accuracy and error value of the measurement system used in this study. This process was carried out by assembling the experimental setup using the tools and materials being tested, as illustrated in Figure 1.

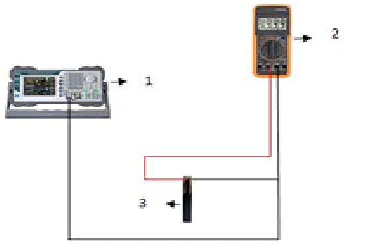

Figure 1. Design of the measurement setup for the permittivity and conductivity of CPHW-based activated carbon

Description: 1) Generator function as a device to regulate the input voltage supplied to the circuit. 2) Multimeter serves as an instrument to measure and display the electric current flowing through the circuit. 3) Research sample acts as the dielectric material in the capacitor system

The current values in the circuit, as measured by the multimeter, were used to calculate the electrical conductivity of the CPHW-based activated carbon. These values were then employed to determine the resistance and electrical conductivity under a DC voltage source. Under AC current, the capacitance and dielectric constant values were obtained as a result of frequency variation.

Data Analysis

Equations (1) dan (2) are used to calculate the electrical conductivity of the material and its dielectric constant.

$$\sigma = L\ RA \quad (1)$$

Where σ represents the electrical conductivity with unit of siemens per meter (S/m).

$$\varepsilon = Cd\ /A\varepsilon 0 \quad (2)$$

Where ε is the dielectric constant of the material, d is the distance between the two plates in meters (m), C is the capacitance in farads (F), ε_0 is the permittivity of free space (8,854 x 10^{-12}F/m), and A is the area of Plates in square meters (m^2).

4. Results and Discussions

CPHW-Based Actived Carbon Results

The carbonization process was carried out to decompose the lignin and cellulose components into carbon. This was done by heating the charcoal samples in a furnace at a temperature of 400°C for one hour. The activated carbon produced from the cocoa pod husk (CPHW) through this process is shown in Figure 2. The preparation of CPHW-based activated carbon involved two activation stages. The first stage, known as chemical activation, aimed to degrade organic molecules during the carbonization process. In this stage, potassium hydroxide (KOH) was used as the activating agent to enlarge the pore size, which increased with higher KOH concentration. The second stage, known as physical activation, was conducted to remove impurities remaining in the CPHW-based activated carbon and to promote the formation of new pore structures [5].

Figure 2. Activated Carbon Derived From Cocoa husk (CPHW)

Electical Conductivity Measurement Result of CPHW Activated Carbon

To observe the relationship between voltage and electric current, tests were conducted with voltage variations of 30, 35, 40, 45, and 50 volts. The experimental results are presented in Table 1.

Table 1. Relationship Between Voltage and Current

No	Voltage (Volt)	Current (A)
1	30	$2.4x10^{-4}$
2	35	$3.2x10^{-4}$
3	40	$4.0x10^{-4}$
4	45	$4.8x10^{-4}$
5	50	$5.6x10^{-4}$

The measurement results showed a resistance (R) value of 9476.2 Ω and a coefficient of determination (R^2) of 0.987, indicating that the data exhibited an excellent level of fit to the linear model used. Furthermore, Equation (1) was applied to calculate the electrical conductivity of the CPHW-based activated carbon. With a parallel plate area of 0.0064 m^2 and a plate separation distance of 0.0005 m, the calculated electrical conductivity value was 5.5×10^{-5} S/m. This conductivity range, which lies between 10^{-6} and 10^4 S/m, classifies the CPHW-based activated carbon as a semiconductive material.

Capacitance Measure Result of CPHW – Based Activated Carbon

The measurement results showed a resistance (R) value of 9476.2 Ω and a coefficient of determination (R^2) of 0.987, indicating that the data exhibited an excellent level of fit to the linear model used. Furthermore, Equation (1) was applied to calculate the electrical conductivity of the CPHW-based activated carbon. With a parallel plate area of 0.0064 m^2 and a plate separation distance of 0.0005 m, the calculated electrical conductivity value was 5.5×10^{-5} S/m. This conductivity range, which lies between 10^{-6} and 10^4 S/m, classifies the CPHW-based activated carbon as a semiconductive material.

Table 2. Relationship Between Impedance and Frequency

No	Impedance (Ω)	Frequency (Hz) (A)
1	$7.6x10^3$	$1.0x10^4$
2	$6.4x10^3$	$2.0x10^4$
3	$5.5x10^3$	$3.0x10^4$
4	$5.1x10^3$	$4.0x10^4$
5	$4.9x10^3$	$5.0x10^4$
6	$4.7x10^3$	$6.0x10^4$
7	$4.5x10^3$	$7.0x10^4$
8	$4.4x10^3$	$8.0x10^4$
9	$4.3x10^3$	$9.0x10^4$
10	$4.2x10^3$	$10.0x10^4$

The capacitive reactance (Xc) value was determined using Equation (6) after obtaining the impedance values. Subsequently, the capacitance (C) was calculated using the same equation. The capacitance values were found to be influenced by the applied frequency, as presented in Table 3, which shows the relationship between capacitance and frequency.

The measurement results indicate that the capacitance values varied within the frequency range of 10,000 Hz to 100,000 Hz. The capacitance at 10,000 Hz was found to be 1.743×10^{-9} F, while at the highest frequency of 100,000 Hz, the capacitance decreased to 3.019×10^{-10} F.

Table 3. Realtionship Between Capacitance and Frequency

No	Capacitance (F)	Frequency (Hz) (A)
1	$1.7x10^{-9}$	$1.0x10^{4}$
2	$9.6x10^{-10}$	$2.0x10^{4}$
3	$7.8x10^{-10}$	$3.0x10^{4}$
4	$6.8x10^{-10}$	$4.0x10^{4}$
5	$6.0x10^{-10}$	$5.0x10^{4}$
6	$5.3x10^{-10}$	$6.0x10^{4}$
7	$4.7x10^{-10}$	$7.0x10^{4}$
8	$4.0x10^{-10}$	$8.0x10^{4}$
9	$3.8x10^{-10}$	$9.0x10^{4}$
10	$3.0x10^{-10}$	$10.0x10^{4}$

Dielectric Permittivity Measurement Result of CPHW- Based Actived Carbon

The dielectric permittivity value of the CPHW-based activated carbon decreased as the frequency increased. During the measurement conducted at a frequency of 10,000 Hz, the dielectric permittivity was found to be 65.52, while other values corresponding to different frequencies are presented in Table 4.

The dielectric permittivity values indicate that higher applied frequencies result in lower permittivity values. This finding is consistent with the results reported by X. Hong, W. Yu, and D.D.L. Chung [6][7], who also investigated the relationship between frequency and the dielectric behavior of activated carbon. Their study revealed that the dielectric permittivity decreases with increasing frequency, confirming the same trend observed in this research [6].

The results of this study show that as the frequency increases, the range of decrease in dielectric permittivity becomes smaller. Table 4 illustrates the pattern of the electrical permittivity of CPHW-based activated carbon tested within the frequency range of 10,000 Hz to 100,000 Hz. The polarization observed in the CPHW-based activated carbon is attributed to the separation of space charges, which are free charges distributed within the dielectric region of the activated carbon material. This space-charge polarization contributes significantly to the overall dielectric behavior, particularly at low frequencies, where charge accumulation at interfaces is more pronounced.

Table 4. Relationship Between Dielectric Permittivity and Frequency

No	Permittivity (F/m)	Frequency (Hz)
1	65.52	$1.0x10^{4}$
2	49.24	$2.0x10^{4}$
3	40.55	$3.0x10^{4}$
4	35.87	$4.0x10^{4}$
5	28.96	$5.0x10^{4}$
6	23.66	$6.0x10^{4}$
7	22.01	$7.0x10^{4}$
8	19.90	$8.0x10^{4}$
9	17.75	$9.0x10^{4}$
10	16.15	$10.0x10^{4}$

5. Conclusion

According to the study, the activated carbon derived from cocoa pod husk (CPHW) exhibited an electrical conductivity value of 4.755×10^{-5} S/m, indicating semiconductive properties. This suggests that the material can be utilized for low-scale electronic applications or natural material–based sensors. Furthermore, the measurement results showed that with increasing frequency, the dielectric permittivity of the CPHW-based activated carbon decreased significantly—from 65.52 at 10,000 Hz to 16.15 at 100,000 Hz. This decline reflects a dielectric dispersion phenomenon, providing important insight into the frequency response behavior of the material under alternating current (AC) conditions.

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