Synthesis of Silicon Dioxide (SiO$_2$) from Reeds Biomass (Imperata cylindrica) and The Analysis of Electrical Properties (Study Cases: Impedance, Resistance, Capacitive Reactance, Inductive Reactance)

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Abstract. Silicon dioxide (SiO$_2$) has successfully synthesized from reeds biomass (imperata cylindrica) by annealing temperature variation at 500, 600, 700 oC. The result of the synthesis has analyzed using LCR meters to calculate the electrical properties including resistance (R), reactance (X) (delta inductive reactance (XL) and capacitive reactance (XC)), impedance (Z) in the frequency range at 50 Hz to 5 MHz. The resistance (R), reactance (X) (delta inductive reactance (XL) and capacitive reactance (XC)), impedance (Z) value according to reversible electric current rules.

1. Introduction

Reeds (Imperata cylindrica) are natural vegetation that is very abundant in tropical and subtropical areas. In Indonesia, It has a community of 8.5 million hectares, especially in extended rainy areas. Imperata plants are wild plants and easy to reproduce [1]. Reed is also known as one of the most harmful and difficult to eradicate pest plants. It is caused by controlling the scope of the soil or rhizomes. People use reed for making roofs, briquettes, and livestock, but their use is limited [2]. People also usually use the roots of the reed as medicine, and the leaves dispose of as agro-waste. The ash from the leaves of the reed can use as a material for making silica.

Naturally, silica is found in quartz sand (quartz), opal rock, flint, and gemstones. Silica has the properties of colorless crystals, specific gravity 2.2 -2.6 insoluble in water and acids except for HF, soluble in molten alkali, and has a melting point between 1600 °C-1750 °C and will sublime at a temperature of 1750 °C [3].

This study aims to study and analyze the ignition temperatures on the silica content of reeds and measure its electrical properties, including resistance (R), reactance (X) (delta inductive reactance (XL) and capacitive reactance (XC)), impedance (Z) in the frequency range at 50 Hz to 5 MHz.
2. Method
The method was carried out in 6 stages: (i) 1 g of reed leaves soaked in 12 ml of 3% technical HCl at 200 °C for 3 hours; (ii) rinsed with aquabides until neutral (pH = 7). ); (iii) reed leaves sample was dried in an open space; (iv) reed charcoal calcinated at annealing temperatures of 500 °C, 600 °C, and 700 °C; (v) extraction of SiO2 from reed ash samples dried in the furnace at a temperature of 800 °C with a velocity temperature of 100 °C/hour (calcination process); and (vi) the analysis of electrical properties includes resistance (R), the difference between capacitive reactance and inductive reactance (X), and impedance (Z) using a LCR meter.

3. Result and Discussion
Silicon dioxide from Reed biomass was successfully synthesized and analyzed using XRD at 500 °C, 600 °C, and 700 °C. The XRD results show that the synthesis of silicon dioxide formed is amorphous, as shown in Figure 1 [4].

![XRD graph of silicon dioxide from cogon grass at ashing temperature of 500 °C, 600 °C, and 700 °C](image)

The result of the synthesis have analyzed using LCR meters to calculated the electrical properties including resistance (R), reactance (X) (delta inductive reactance (XL) and capacitive reactance (XC)), impedance (Z) in the frequency range at 50 Hz to 5 MHz.

3.1. Resistor circuits (R)
A resistor (R) carries alternating current when connected to an alternating voltage source. The resistor circuit alternating current reduces the electric potential in the circuit or limits the incoming electric current. The current and voltage in the resistor circuit have the same phase when connected to an alternating voltage source.

Figure 2 shows the resistance data (R) at frequency (a) 50 Hz to 100.000 Hz (low frequency); (b) 100.000 Hz to 3.000.000 Hz; (c) 3.000.000 Hz to 5.000.000 Hz of SiO2 from reeds at an annealing temperature of 500 °C (black line), 600 °C (blue line), and 700 °C (red line). It shows the similar patterns, as the increasing frequency causes the resistance value decreases. It probably occurs because the increasing frequency causes the lower current and voltage produced by the resistor of SiO2 from reeds at annealing temperatures of 500 °C, 600 °C, and 700 °C.
Silicon has the properties of (a) high mobility, (b) small dielectric constant, (c) large thermal conductivity, (d) good heat dissipation, and (e) low impurity ionization energy. These properties make silicon widely used as a semiconductor material, such as a rectifier diode, thyristor (SCR), and others. Silicon compound, SiO\textsubscript{2} (quartz) is often used in optical instruments with a refractive index of 1.54.

Semiconductors have resistance with a negative temperature coefficient, meaning that the resistance of the semiconductor decreases with increasing temperature [5].

3.2. Reactance circuit (X) (difference between inductor reactance (XL) and capacitive reactance (XC)
3.2.1. Inductor reactance (XL)

An inductor has a resistance called inductive reactance (XL) connected to an alternating voltage source. The voltage across the inductor reaches its maximum value a quarter of a period faster than the current. The inductive reactance (XL) depends on the angular frequency of the current and the self-inductance of the inductor and written in equation (1):

\[ X_L = \omega L \]  

(1)
3.2.2. Capacitive reactance (XC)

A capacitor has a resistance called capacitive reactance (XC) connected to an alternating voltage source. The electric current in the inductor reaches its maximum value four times faster than its voltage. The capacitive reactance (XC) depends on the magnitude of the capacitance value of the capacitor and the angular frequency of the current and written in equation (2):

\[ X_C = \frac{1}{\omega C} \]  

(2)

Reactance X is the difference between inductor reactance (XL) and capacitive reactance (XC) when connected to an alternating voltage source.

Figure 3 shows the reactance data (X) (difference between inductor reactance (XL) and capacitive reactance (XC)) at frequency of (a) 50 Hz to 100,000 Hz (low frequency); (b) 100,000 Hz to 3,000,000 Hz (medium frequency); (c) 3,000,000 Hz to 5,000,000 Hz (high frequency) of SiO$_2$ from reeds at an annealing temperature of 500 °C (black line), 600 °C (blue line), and 700 °C (red line). It shows the similar patterns, as the increasing frequency causes the reactance (X) value to decrease. It probably occurs because the increasing frequency causes the lower current and voltage produced by the reactance (X) of SiO$_2$ from reeds at annealing temperatures of 500 °C, 600 °C, and 700 °C.
The equation or formula for inductive reactance above shows that if either the Frequency or Inductance increases, the Inductive Reactance value will also increase as a whole. If the Frequency is close to infinity, then the value of inductive reactance will also increase to infinity as in an open circuit.

However, if the frequency is close to 0 or as in DC voltage, the inductive reactance will decrease until it reaches 0 in a short circuit. It means the value of Inductive Reactance is proportional to Frequency. In other words, the Inductive Reactance will increase as the frequency increases.

The capacitive reactance is inversely proportional to the Frequency. If the Frequency increases, then the capacitive reactance will decrease and vice versa. Capacitors are equal, and this applies only to ideal capacitors [5].

3.3. Impedance circuits (Z)

![Impedance circuits](image)

**Figure 4.** The impedance data (Z) at frequency of (a) 50 Hz to 100.000 Hz (low frequency); (b) 100.000 Hz to 3.000.000 Hz (medium frequency); (c) 3.000.000 Hz to 5.000.000 Hz (high frequency) of SiO₂ from reeds at an annealing temperature of 500 °C (black line), 600 °C (blue line), and 700 °C (red line).
Electrical impedance is the electrical resistance of an electronic component to the current flow in a circuit at a particular frequency. Impedance is fundamentally more complex than resistance (R) due to the effects of capacitive reactance (XL) and inductive reactance (XC), which vary with the frequency of the current passing through the circuit. Electrical Impedance Formula according to equations (3) and (4):

\[ Z = \sqrt{R^2 + (XL - XC)^2} \]  
\[ Z = \sqrt{R^2 + (X)^2} \]  

The impedance data analysis (Z) in equation (4) combines data from resistance (R) with reactance data (X) in equations (1) and (2), which produces impedance data (Z) according to Figures 3(a), 3(b), and 3(c).

Figure 4 shows the impedance data (Z) at the frequency of (a) 50 Hz to 100.000 Hz (low frequency); (b) 100.000 Hz to 3.000.000 Hz (medium frequency); (c) 3.000.000 Hz to 5.000.000 Hz (high frequency) of SiO2 from reeds at an annealing temperature of 500 °C (black line), 600 °C (blue line), and 700 °C (red line). It shows the similar patterns, as the increasing frequency causes the reactance (X) value to decrease. It probably occurs because the increasing frequency causes the lower current and voltage produced by the reactance (X) of SiO2 from reeds at annealing temperatures of 500 °C, 600 °C, and 700 °C.

The magnitude of the impedance Z of a circuit is equal to the maximum value of the potential difference, or voltage, V (volts) across the circuit, divided by the maximum value of the current I (amperes) through the circuit, or simply \( Z = \frac{V}{I} \). The unit of impedance, like that of resistance, is the ohm. Depending on the nature of the reactance component of the impedance (whether predominantly inductive or capacitive), the alternating current either lags or leads the voltage. It is consistent with the silicon dioxide impedance data from reed biomass. The difference in potential value decreases with increasing frequency perpendicular to the decrease in voltage and electric current [6].

4. Conclusion
The synthesis results have analyzed using LCR meters to calculate the resistance, capacitive reactance, and inductive reactance, the impedance value according to reversible electric current rules. The increasing frequency causes the value decrease of the resistance (R), reactance (X) (difference between inductor reactance (XL) and capacitive reactance (XC)), and impedance (Z).

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