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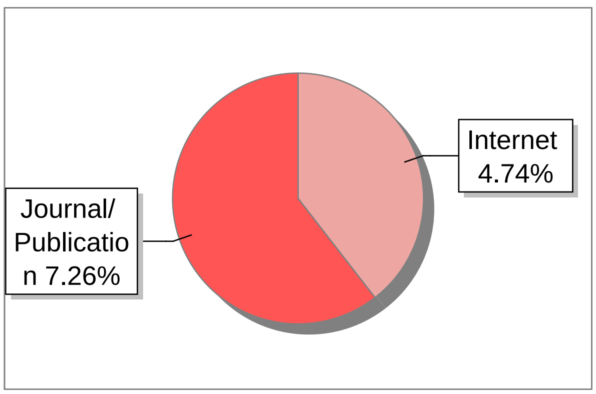

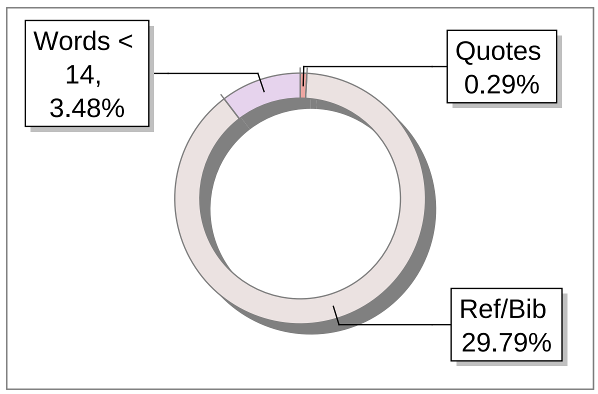

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RESEARCH

Structural and Electrical Properties of Silica Materials from Rice Husks

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ABSTRACT This study aimed to analyze the structural and electrical properties of silica from rice husks recovered by the process of ashing on a medium-scale furnace with a capacity of 15 kg. Rice husks were burned at a heating rate of 1.5°C/min to a temperature of 900°C, where the temperature was retained for 1 hour each at 400°C and 900°C. The methodology of this research was conducted through the process of ashing, extraction of silica, and characterization of its structural electrical properties. The silica extracted from rice husk ash had a relatively low water content by the low absorption intensity of the group –OH at 3610 cm^{-1}. The silica was dominated more by the siloxane group (Si-O-Si) compared with the silanol group (Si-OH). Based on XRD analysis, the silica structure was confirmed as tetragonal. The silica also had a decreased resistance, impedance, and inductance as the frequency increased. These results indicate that the obstacles contained in silica content decrease with an increase in frequency. The decreasing of dielectric constants was caused by the frequency affecting the capacitance; i.e., increased frequency caused more waves to be transmitted each second. The electric current was turned before the capacitor plate was fully charged, which caused quick charge drainage in the capacitor plate and therefore reduced the ability of a material to store the electric charge.

1. INTRODUCTION

Rice production in Indonesia is large enough to give it a great potential to produce rice husks. Data from Statistics Indonesia (c2021) show that by 2020, rice production (ATAP) reached 54.65 million tons (dry basis), an increase of 45.17 thousand tons (0.08%) over 2019. The production of husks from rice milling is usually about 20–30% of the dry grain (Casnan 2011), while the ash yield from the burning of rice husks is about 18% (An et al. 2011).

Husk ash generally contains a high amount of silica, around 87-97% (Rozainee et al. 2008; Larbi 2010; Patil et al. 2014). A silica fraction that is close to or below 90% is likely the result of the contamination of husk samples by other substances whose silica content is low (Umeda and Kondoh 2010; Oyekan and Kamiyo 2011; Madrid et al. 2012). Rice husk ash produced by controlled high temperatures (500–600°C) using a rice husk furnace can be used for various chemical processes (Kumar et al. 2012; Kordatos et al. 2013; Li et al. 2013). Silica produced from rice husks has several advantages compared with silica from quartz sand; for example, the rice husk ash silica has fine grains (Li et al. 2013), is more reactive (Afolayan et al. 2015), can be obtained easier and at a relatively low cost (Madrid et al. 2012), and is supported by abundant and renewable raw materials (Afolayan et al. 2015; Shen et al. 2014). Rice husk ash consequently has significant potential as a source of silica, which itself is a material with a broad application (Kumar et al. 2012; Emdadi et al. 2015). However, prior to its application, the characteristics of silica produced from rice husks, such as its structure and electrical properties need to be studied first. Besides the use of the physical components of rice husk ash for creating cement composites (Afolayan et al. 2015; Rattanasak et al. 2010), industries such as cosmetics, electronics, film, and toothpaste have used silica raw materials (Kordatos et al. 2013).

This study aimed to analyze the structural and electrical properties of silica from rice husks recovered by the process of ashing on a medium-scale furnace with a capacity of 15 kg. Rice husks were burned at a heating rate of 1.5°C/min to a temperature of 900°C. A scale-up process was necessary to be carried out to increase the production capacity of the silica so that from the experimental results medium a multiplication model could be made for industrial use (Casnan et al. 2019a).

2. MATERIALS AND METHODS

The materials used in this study were rice husks, acid solution (3%), and aquabidest. The research consisted of rice husk cultivation through a high-temperature combustion process, silica extraction, and silica characterization.

2.1 Ashing Rice husk ashingwas carried out in amedium-scale furnace with a capacity of 15 kg (Figure 1). Rice husks ware burned at a heating rate of 1.5°C/min to a temperature of 900°C, where the temperature was retained at 400°C and 900°C each for 1 h (Casnan et al. 2019b). Of the rice husk ash that was burned, sample trays 1, 4, and 8 were selected. 2.2 Silica extraction Rice husk ash was washed using hydrochloric acid (HCl) 3% technical grade. The purpose of this washing process was to remove the impurities from the recovered silica. The composition for the washing process was 12 mL HCl 3% for each gram of husk ash. The mixture was then heated over a hotplate at a temperature of 200°C and stirred using a magnetic stirrer at a speed of 240 rpm for 2 h (Rattanasak et al. 2010). It was then washed using hot aquabidest sev- eral times until an acid-free condition was achieved (tested using a litmus paper). The slurry was then filtered using ash-free filter paper. The filtration result (residue + filter paper) was then heated in a furnace at 1000°C until white silica remained. The sample was cooled in the furnace to a temperature approximating room temperature (Casnan et al. 2019b). 2.3 Characterization of silica structure properties and electrical properties Silica ash was tested with Fourier-transform infrared spec- troscopy (FTIR), using a Perkin-Elmer Spectrum One. X- ray diffraction (XRD), a diffraction process from a Cu-ray source on the K line with a wavelength of 1.5406 Å, was also performed. The firing angle for the silica was between 5 and 85°. The XRD tool usedwas the SHIMADZUXRD 7000 X-Ray MAXima Diffractometer. Meanwhile, the electrical properties test used an LCR meter, the HiTESTER 3522-50. 3. RESULTS AND DISCUSSION 3.1 Silica The silica thatwas produced from the pyrolysis processwas soft and white in color. 3.2 Fourier-transform infrared spectroscopy FTIR was used to identify the functional groups in the sil- ica samples, where each functional group has an absorption characteristic in a certain wave number. The silica infrared (a) (b) FIGURE 1. Medium-scale furnace with a capacity of 15 kg (a) before com- bustion and (b) after combustion. absorption pattern resulting from rice husk processing is shown in Figure 2. The IR spectra were compared to those from commercial silica, and showed a similar pattern. The absorption band at the wavenumber of 471 cm-1 indicated a bending vibration of the siloxane group (Si-O-Si). The absorption band at 795 cm-1 indicated a Si-O symmetrical stretching vibration of Si-O-Si (Nazopatul et al. 2018). Ab- sorption bands at 1095 cm-1 and 1080 cm-1 indicated the presence of a Si-O asymmetrical stretching vibration of Si- O-Si. Absorption bands at around 3610 cm-1 indicated the stretching vibration of -OH from Si-OH or water (Aminul- lah et al. 2018), at the heating rate of 1.5°C/min. Based on the IR spectra, it was found that the silica ex- tracted from rice husk ash has a relatively low water con- tent and is more likely dominated by the siloxane group (Si- O-Si), as opposed to the silanol group (Si-OH). This is indi- cated by the low intensity of wide absorption of the cluster –OH at 3610 cm-1. 3.3 X-ray diffraction XRD was used to identify the degree of crystallinity and pu- rity by analyzing its diffraction pattern. The XRD results were matched with the database from the Joint Commit- tee on Powder Diffraction Standards (JCPDS), International Centre for Diffraction Data (ICDD). A similar pattern was found between the experimental silica and commercial sil- ica (Figure 3). The peak of the silica at point 2 in tray 1 was 22.04° hkl (1018), 27.82° hkl (213), 31.52° hkl (2114), 36.28° hkl (220), 44.74° hkl (2131), and 47.38° hkl (2134). The silica peaks in tray 4 were 21.94° hkl (0020), 27.54° hkl (213), 31.52° hkl (2114), 36.16° hkl (220), 43.04° hkl (0039), 47.14° hkl (2134), and 57.32° hkl (428). The silica peaks in tray 8 were 22.06° hkl (1018), 27.60° hkl (213), 31.54° hkl (2114), 36.28° hkl (220), 44.84° hkl (2131), 47.38° hkl (2134), and 57.64° hkl (428). This suggests that the three samples did not have significant FIGURE 2. FTIR spectra of rice husk ash silica at heating rate of 1.5°C/min. FIGURE 3. X-ray diffraction pattern of rice husk ash silica. 68 Casnan et al.

differences, because the treatments given for each sample were essentially the same (Adam and Iqbal 2010; Sintha et al. 2017). It was also determined that the structure of the silica using the Cohen method was tetragonal. Furthermore, by using the Cramer method, the lattice constants of silica tray 1 were obtained, namely a = b = 6.117 Å and c = 72.033 Å, while those for tray 4 were a = b = 8.010 Å and c = 91.357 Å, and those for tray 8 were a = b = 7.891 Å and c = 89.789 Å. Referring to JCPDS ICDD no. 14-0260, the lattice constants of the silica were a = b = 9.92 Å and c = 81.5 Å.

3.4 Resistance

Resistance is defined as the ratio of the voltage (V) to the electric current (I). The unit of resistance is Ohm. The increase of the resistance of material will reduce the electric current through the material. The electric current is a flow of electrons that will interact with the atoms in the wire material. The atoms in the wire act as an obstacle for electrons so that the larger the number of atoms in the wire, the smaller the electric current (Aminullah et al. 2018).

An ideal conductor has a very small resistance, while an ideal insulator has a very large resistance. Conductivity is a property of material reciprocal of the resistance. Electrical conductivity is an analogy of thermal conductivity (Adli et al. 2018). The conductivity of a material is inversely proportional to its resistance. The resistance of a material depends on the length, cross-sectional area, material type, and temperature (Irzaman et al. 2018).

Figure 4 shows a decrease in the resistance with a higher frequency. Differences in resistance at low frequencies indicate an obstacle due to the silica content. The resistance decreases as the frequency continues to increase, indicating that the resistance in the deepest component of silica becomes smaller.

3.5 Impedance

As Figure 5 shows, there was a decrease in the impedance value with increasing frequencies. The difference of impedance at a low frequency is due to the increasing distance between electrodes, wherein the mobilization of electrons in the material consequently takes a longer distance, thus increasing the impedance (Aminullah et al. 2018), along with the electric current on the material becoming smaller. The data patterns at lower frequencies were steeper, while at high frequencies the results were quite similar for all trays. This indicates silica resistance at low frequencies. The impedance decreases with an increase in frequency, which means that the resistance in the deepest components of silica is getting smaller. At the saturation condition, the impedance stays similar even when the frequency is raised.

3.6 Inductance

Inductance is the property of the electric circuit to generate electric potential proportionally to the changing of the electric current in the circuit, also known as self-inductance. When the electric potential in a circuit is caused by changes in the current of another circuit, it is called mutual inductance.

The relationship between resistance and impedance is similar because impedance is an overall resistance whose components include both the resistance (R) and inductance (L). Therefore, the trend for the impedance in the circuit is also similar to that for resistance (Figure 6). The unit

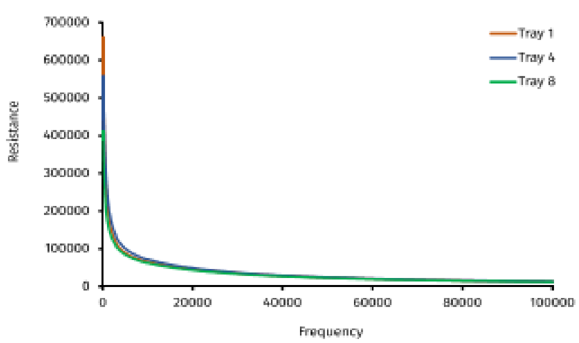

FIGURE 4. Rice husk ash silica resistance vs. frequency.

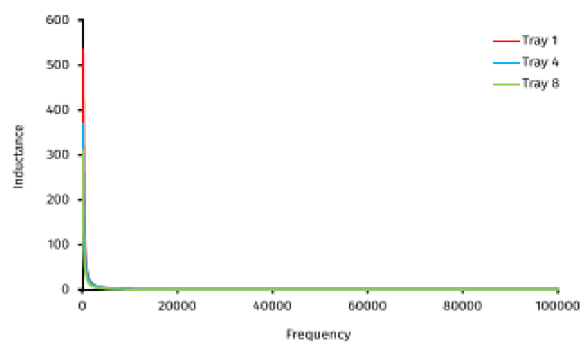

FIGURE 6. Rice husk ash silica inductance vs. frequency.

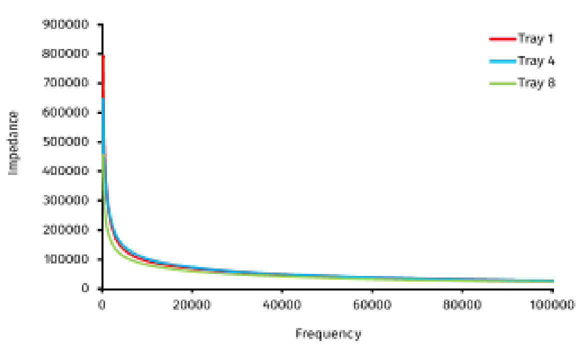

FIGURE 5. Rice husk ash silica impedance vs. frequency.

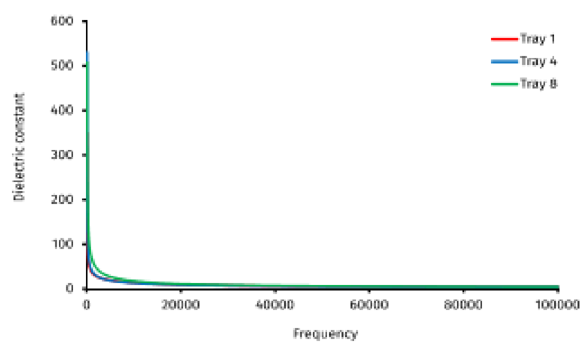

FIGURE 7. Dielectric constants vs. frequency in rice husk ash silica.

of resistance is Ohm equal to impedance (Aminullah et al. 2018). A similar trend was also observed for inductance, as displayed in Figure 6, where the inductance (L) decreased with increasing frequency.

3.7 Dielectric Constants

The dielectric constant is a comparison of electrical energy stored in the material for a given electric potential, relative to a vacuum. It is calculated based on Equation 1 (Nazopatul et al. 2018).

$$k = \frac{Cd}{\epsilon_0 A} \quad (1)$$

where k is the dielectric constant of a material, ϵ_0 is the vacuum dielectric constant (8.854×10^{-12} F/m), C is the capacitance (F), d is the distance between plates (m), and A is the plate area (m^2).

The influence of frequency towards the dielectric constant was similar to that of the previous properties, where its value decreased with a higher frequency, as displayed in Figure 7. The decreasing of dielectric constants was due to the varying frequency affecting the capacitance (Nazopatul et al. 2018). Silica samples for each treatment at frequencies under 300 Hz experienced a significant decrease of dielectric constants. Meanwhile, at medium and high frequencies, the reduction tended to be more gradual. The decreasing of dielectric constants was caused by the frequency impacting the capacitance; i.e. the increased frequency resulted in more waves being transmitted each second. The electric current was turned before the capacitor plate was fully charged, which caused a quick charge drainage in the capacitor plate and therefore reduced the ability of the material to store the electric charge.

4. CONCLUSIONS

In this study, silica was produced from rice husk ashing in a medium-scale furnace with a capacity of 15 kg. Rice husks were burned at a heating rate of 1.5°C/min to 900°C, with retainment at 400°C and 900°C each for 1 h. The extracted silica had a relatively low water content, which was reflected in the low absorption intensity of the cluster -OH at 3610 cm^{-1}. The silica was also dominated more by the siloxane group (Si-O-Si), compared with the silanol group (Si-OH). Based on the XRD analysis, the structure of the silica was tetragonal. Meanwhile, concerning, the electrical properties, the silica showed a reduction in resistance, impedance, and inductance with higher frequencies. This suggested that the electrical obstacles due to the silica content decreased as the frequency increased. The decreased dielectric constants were caused by the varying frequencies affecting the capacitance value. The increased frequency caused more waves to be transmitted each second. Then, the electric current turned before the capacitor plate was fully charged, which caused a quick charge drainage in the capacitor plate and therefore reduced the ability of the silica to store the electric charge.

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AUTHORS' CONTRIBUTIONS

CSN, EN, HH, IR, and ER jointly coordinated and designed the research. CSN and PRW collected data. CSN and AK analyzed data and provided a translation. All authors participated in manuscript writing and approved the final version of the article.

COMPETING INTERESTS

The authors declare that they have no conflict of interest.

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