Effects of Grain Sizes on Rice Husk Ash Composite as Microwave Absorber

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Abstract. Electromagnetic interference affects human’s health and interrupt the electrical equipment’s performance. Metallic materials commonly used as microwave absorber is not cost-effective and too heavy. The agriculture waste from farming activities can be an alternative for inexpensive microwave absorbing material. Agriculture waste contain organic compound which has carbon element in their composition. Rice husk is one of the agriculture waste known to have high carbon content and also lightweight which are desired to be a good microwave absorber. Therefore, rice husk ash is used and the effect of the rice husk grains sizes as microwave absorber is investigated. The reflection loss for smallest grain size 2.5 × 10⁻³ cm was achieved -22.7 dB which is the highest which also possess smallest pore size which is 0.432 µm indicates high surface area.

1. Introduction

Electronic devices are widely use which lead to the undesired electromagnetic interference (EMI) affects the human health and disturb the performance of electrical devices or equipment. The exposure of EMI on human cell can lead to development of cancer or stimuli on electrically excitable tissue which can cause brain malfunction, headache and memory loss (1). Metallic composite materials are mostly used to manufactured as electromagnetic shielding material due to its effectiveness in shielding and high electrical conductivity. However, the huge penalty for this metallic material are heavy weight and not cost-effective (2).

The use of agricultural wastes produced through farming activities are highly demand in research as microwave absorber material. These are some of agricultural wastes which had been used as
alternative for microwave absorber including rice husk, rice straw, sugarcane bagasse and banana leave (etc) that would add economic value to the existing microwave absorbing material which create inexpensive alternative while reducing the cost of waste disposal (3-5). About 97% of rice husk was produced from the processing of rice mills from developed country and usually was burned in order to disposed it. This will cause air pollution and lead to health problems (4, 5). Rice husk ash is highly porous, very high in surface area and lightweight (6). Porous carbon usually prepared from rice husk due to the cost - effective and cheap energy source instead of been discarded. It also low cost compared to others polymer composite and eco-friendly to the environment (7, 8). Not only that, the rice husk ash contains about 35-37 % of carbon which make the rice husk ash the potential useful as a microwave absorber and other applications. When the microwave passes through the rice husk ash, the carbon will reduce the effect of the wave (9). Carbon has high surface area and pore structure which contribute to the reducing the attenuation of microwave radiation (10). Not only that, carbon has good dielectric properties with high value of loss tangent (tan δ) which allow for dielectric heating (11, 12). The importance of carbon in the role of microwave absorption has been stated by several researchers where carbon can enhance the transformation of microwave energy to thermal energy contributed from their permeability and permittivity properties (12, 13). In this work, we are interested in studying the effect of the grain size of rice husk ash towards the microwave absorber performance based on the S-parameter using Agilent E8362B performance network analyser.

2. Methodology

2.1 Microwave Absorber Fabrication

The works begin with the collection of raw rice husk ash from the paddy and rice industry, BERNAS, Sungai Limau, Yan, Kedah. The rice husk ash is produced in an open air factory and uncontrolled burning. The temperature used in the burning process is 300 °C and the treated rice husk is black in colour which indicates high carbon content. Then, the rice husk ashes were dried in the oven in 70-80 °C for five hours to ensure they were completely dried. In order to get different grain sizes characteristic, the RHA was grinded for three hours. The grains obtained were sieved by using sieving machine in order to separate accordingly to the diameter of the sieve container. Subsequently, rice husk ash (RHA) was mixed with polyester and methyl ethyl ketone peroxide (MEKP). The function of polyester resin is to bind the RHA without creating any new bonding. Meanwhile, the MEKP act as hardening agent in order to harden the samples during the microwave absorber fabrication process. The RHA mixtures were then added to the mould until it fills the space with a dimension of 22.86 mm (length) × 10.16 mm (width) × 5 mm (thickness). After being added into the mould, the RHA mixture was compressed using a clamp in 30 minutes time before taking it out. Then the weight was measured to calculate the density of each samples. The RH samples were left in room temperature for three hours to ensure the sample was totally dried and hardened. The mixture of MEKP and Polyester was which act as control sample is also fabricated. The RHA and control samples were tabulated accordingly based on the grain size, weight and density. The characterizations were performed using Scanning Electron microscopy (SEM) and Energy Dispersive X-ray Spectroscopy (EDX) in order to determine the surface morphology and element composition.
2.2 Reflection and Absorption Measurement

The reflection loss, $S_{11}$ of rice husk ash can be obtained using the S-parameter data measured by using rectangular waveguide method. The RHA sample will be fitted in the inner dimension of the waveguide at the frequency of 8.2 – 12.0 GHz. The thickness of the sample usually less than a quarter of the rectangular waveguide measurement wavelength. The samples should be fitted properly in order to get accurate result. The standard thru-reflect-line (TRL) calibration technique is required which to avoid unwanted losses/reflection in the inner wall of the waveguide as well as to achieve zero reference plane for the measurement. (13). An Agilent network analyser was used to measure the microwave absorption and reflection properties RHA and control samples, respectively.

3. Result and Discussion

3.1 Density

After the Control (C0) and rice husk ash samples with different grain sizes $2.5 \times 10^{-3}$ cm, $1.0 \times 10^{-1}$ cm, $3.0 \times 10^{-1}$ cm and $5.0 \times 10^{-1}$ cm of RHA have been compressed, the weights were measured in order to manually compute the density (Table 1) by using equation (1).

\[
\text{Density } (\rho) = \frac{\text{Mass } (g)}{\text{Volume } (cm^{-3})} \quad (1)
\]

The density is dependent on grain sizes and the weight of each samples. The weight and density for each sample decreases with grain sizes, respectively (Table 1). Smaller grain size will be more compact during the compression process and the grains will be closed together where the size of samples has been fixed with similar dimension. Therefore, it will reduce the buoyancy of the samples. The highest density of R1 which has smallest grain size ($2.5 \times 10^{-3}$ cm) has been obtained in this work. Reflection loss of the samples might be affected by the different of grain sizes of rice husk ash. As the grain size decrease, the surface area increase, therefore the interaction between the microwave with material increase. This will increase the absorption of microwave instead of been reflected or transmitted through the rice husk samples.
Table 1. The density value for different RHA samples and Polyester Resin.

| Sample | Grain sizes (cm) | Weight (g) | Density (g/cm$^{-3}$) |
|--------|-----------------|------------|----------------------|
| R1     | $2.5 \times 10^{-3}$ | 1.72       | 1.48                 |
| R2     | $1.0 \times 10^{-1}$ | 1.56       | 1.34                 |
| R3     | $3.0 \times 10^{-1}$ | 1.47       | 1.27                 |
| R4     | $5.0 \times 10^{-1}$ | 1.33       | 1.15                 |
| C0     | Polyester resin + MEKP | 1.32       | 1.14                 |
| (Control) |                 |            |                      |

3.2 SEM and EDX analysis

The surface morphology of R1, R2, R3 and R4 at 30k magnification were illustrated in Figure 1. The average pores sizes for R1, R2, R3 and R4 are 0.432 $\mu$m, 0.590 $\mu$m, 1.179 $\mu$m and 13.27 $\mu$m, respectively. R1 with smallest grains size of $2.5 \times 10^{-3}$ cm is more compact and possess smaller pores size and smooth structure shown in SEM. Meanwhile, the R4 has the biggest grain size of $5.0 \times 10^{-1}$ cm has rough surface and larger pore size structure. Smaller pores size indicates high surface area of grain size in total which can increase the interaction of microwave with the sample. Moreover, the R4 shows agglomeration in the sample and all rice husk ash samples structure are not uniform.
EDX result (figure 1(e)), the carbon composition is higher compared to oxygen and silica which is essential in microwave absorber characteristic. The atomic percentage composition of carbon, oxygen and silica are 78.41%, 21.25% and 0.35%, respectively. High carbon content of the rice husk ash samples can be related to high surface area and porous structure which is very useful in enhancing the microwave absorbing properties (10-12).

3.3 Reflection Loss

![Graph showing reflection loss for different samples]

**Figure 2.** The reflection loss of different grains sizes of rice husk ash and polyester resin for microwave absorber

For reflection loss of samples, it is compared using different grain sizes of rice husk ash in the range of 8.2 – 12.0 GHz. The reflection loss achieved by R1, R2, R3 and R4 samples at -22.7 dB, -9.91 dB, -8.42 dB and -7.99 dB at frequency range from 8.2 GHz to 12.0 GHz, respectively (figure 2). In normal phenomenon occurs in microwave absorber, when the rice husk ash absorber is irradiated by the incident wave, the attenuation of incident wave occurred. The incident wave reflects and re-reflects by the rice husk structure as it passed through the absorber. The conversion of heat energy from electromagnetic wave occurs in this process therefore cause the decreasing or reducing of microwave intensity [2]. A material requires to possess reflection loss better than -10 dB, which denotes that the efficiency of the absorbing performance is about 90 percent, therefore indicate a good microwave absorber performance [10]. R1 shows largest value of reflection coefficient which indicates good microwave absorber performance. The best performance of R1 is at frequency 12.0 GHz and higher.
frequency ranges. This indicate that, the small grain size of rice husk ash have significant effect on the microwave absorber performance as R1 possess higher surface area for interaction with microwave radiation. Nevertheless, the process of internal reflection of microwave absorber of R1 also increased which reduce the microwave intensity and increase the absorption of the microwave in the sample.

4. Conclusion

Rice husk ashes with different grain sizes are investigated to determine their reflection loss and microwave absorption capabilities. The rectangular waveguide technique is used to measure the reflected, transmitted and absorbed of microwave radiation by the rice husk ash microwave absorber. The SEM and EDX results show R1 has smaller pore size and the composition of carbon in the all samples also high about 78.41% compared to silica composition. The smaller grain size of R1 give significant effect on the microwave absorbing properties. The smaller the grain sizes of rice husk ash, the smaller the pore sizes possess by the microwave absorber. This will increase the total surface area of R1 which lead to the increase of microwave radiation absorption.

5. Acknowledgement

This work was funded under Fundamental Research Grant Scheme, FRGS, Ministry of Higher Education (203/PJJAUH/6711489).

6. References

[1] Jha BK. 2012. Effects of Electromagnetic Fields on Human Beings and Electronic Devices. Himalayan Physics. p 3:38-9.
[2] Liu Q, Fan T, Zhang D. 2004. Electromagnetic shielding capacity of carbon matrix composites made from nickel-loaded black rice husk. Journal of materials science. p 39(20):6209-14.
[3] Se SM, Shaaban A, Ibrahim IM, editors. 2011. Microwave absorbing material using rubber wood sawdust. Wireless Technology and Applications (ISWTA), 2011 IEEE Symposium on; 2011: IEEE.
[4] Kaur H, Aul GD, Chawla V. 2015. Enhanced Reflection Loss Performance of Square Based Pyramidal Microwave Absorber Using Rice Husk-Coal. Progress In Electromagnetics Research M. p 43:165-73.
[5] Zhang S, Dong Q, Zhang L, Xiong Y. 2015. High quality syngas production from microwave pyrolysis of rice husk with char-supported metallic catalysts. Bioresource technology. p 191:17-23.
[6] Nornikman H, Malek F, Soh P, Azremi A, Ghani S, editors. 2010. Potential of rice husk for pyramidal microwave absorber design. The 2nd International Conference of Institution of Engineering and Technology (IET) Brunei Darussalam Network (ICIET 2010).
[7] Malek MFBA, Cheng EM, Nadijah O, Nornikman H, Ahmed M, Abdul Aziz MZA, et al. 2011. Rubber tire dust-rice husk pyramidal microwave absorber. Progress In Electromagnetics Research. p 117:449-77.
[8] Gao Y, Li L, Jin Y, Wang Y, Yuan C, Wei Y, et al. 2015. Porous carbon made from rice husk as electrode material for electrochemical double layer capacitor. Applied Energy. p 53:41-7.
[9] Iqbal MN, Malek MFBA, Ronald SH, Bin Mezan MS, Juni KM, Chat R. 2012. A study of the EMC performance of a graded-impedance, microwave, rice-husk absorber. *Progress In Electromagnetics Research*. p 131:19-44.

[10] Zahid L, Malek F, Nornikman H, Affendi NAM, Ali A, Hussin N, et al. 2013. Development of Pyramidal Microwave Absorber Using Sugar Cane Bagasse (Scb). *Prog Electromagn Res.* p 137:687-702.

[11] Lam SS, Chase HA. 2012. A review on waste to energy processes using microwave pyrolysis. *Energies*. p 5(10):4209-32.

[12] Shaaban A, Se S-M, Ibrahim IM, Ahsan Q. 2015. Preparation of rubber wood sawdust-based activated carbon and its use as a filler of polyurethane matrix composites for microwave absorption. *New Carbon Materials*. p 30(2):167-75.

[13] Lee YS, Malek F, Cheng EM, Liu WW, You KY, Iqbal MN, et al. 2013. Experimental determination of the performance of rice husk-carbon nanotube composites for absorbing microwave signals in the frequency range of 12.4-18 GHz. *Prog Electromagn Res.* p 140:795-812.