MEASUREMENT OF DIELECTRIC PROPERTIES OF SUGARCANE BAGASSE AND RUBBER TIRE DUST FOR MICROWAVE ABSORBER PERFORMANCE

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ABSTRACT

In microwave measurement, for macroscopic material characteristics investigations, one of the dielectric properties which is relative permittivity, ε_r is often measured. The main objective of this project is to measure the dielectric properties of sugarcane bagasse and rubber tire dust in the range frequency from 2 to 8 GHz. This dielectric property of this material is essential to modeling the microwave absorber performance. This work include a PNA microwave network Analyzer, samples of sugarcane bagasse, sugarcane bagasse mixed with rubber tire dust, the holder samples, Agilent Technologies 85070E Dielectric Probe Kit, the dielectric constant, loss factor, and also the comparison between these three materials.

Keywords: dielectric properties, relative permittivity, dielectric constant, loss factor, dielectric probe kit, sugarcane bagasse, rubber tire dust.

INTRODUCTION

Every material has a unique set of electrical field depends on its dielectric properties. The knowledge of the permittivity of materials is essential to determine the material performance such as in modeling the microwave absorber performance, electronic applications, as well as the recent applications in area of industrial microwave such as processing of rubber and food (Agilent, 2006). Permittivity determined by the polarization of the material and varies significantly over a frequency range. With that, the material's effect and performance on the electric field in microwave frequency can be known. The complex permittivity is generally written as $\varepsilon = \varepsilon' - j\varepsilon$" where ε', the real part is dielectric constant which shows the ability of a material to store energy when the electric field is applied. The imaginary part, ε" is loss factor which is referring to the dissipation of heat or the loss of material to an external electrical field and accounts for the polarization loss. In electromagnetic theory, the electric displacement (electric flux density) is described as

$$D = \varepsilon E \qquad (1)$$

Where ε is the absolute permittivity $\varepsilon = \varepsilon^* = \varepsilon_0 \varepsilon_r$ and ε_r is relative permittivity ε_0 is the free space permittivity $\varepsilon_0 \approx \frac{1}{36\pi} x\, 10^{-9}\, F/m$ and E is the electric field. There are works to determine the dielectric properties of agricultural waste for example rice husk, sugarcane bagasse, oil palm other agricultural waste (Nornikman and Malek, 2010) (Wee *et al*., 2009) (Salleh *et al*., 2011), dielectric properties of granular materials (Trabelsi and Nelson, 2003). Carbon is one of the elements that helped in the charge migration and dipole polarization in a material.

DIELECTRIC PROBE MEASUREMENT

Knowledge of the permittivity and permeability of materials was very crucial in order to model a microwave absorber performance and if those values are known, the material performance is completely determined. In this work, the dielectric properties were measured using Agilent Technologies Dielectric Probe Technique and PNA Network Analyzer. There is some research before that used the dielectric probe technique for measuring the dielectric properties of materials (Savi *et al*., 2014), (Malek *et al*., 2012).The open ended coaxial probe has been used to measure the fabricated sample's dielectric properties.

METHOD AND MATERIALS

Sugarcane Bagasse is also one of the residues and agricultural waste. Sugarcane (*Saccarhum officinarum*) bagasse is a residue produced in large quantities by sugar industries. Sugarcane bagasse has the potential for being used as an alternative material in fabricating the microwave absorbers used in anechoic chamber to eliminate reflected signal (Liyana *et al*., 2013). The content of carbon that occurs naturally in sugarcane bagasse can provide good reflection loss performance.

Sample preparations and measurement set-up

The samples were prepared using the Polyester Resin RP9509 and MEKPO (methyl ethyl ketone peroxide). The samples were fabricated by using the equipment in the lab. The raw materials (sugarcane bagasse) were being dried first and then grinded them by using grinding machine. Two samples using raw materials which are sugarcane bagasse and rubber tire dusts were being fabricated separately first. Then, 25% by weight of sugarcane bagasse were mixed with 75% by weight of

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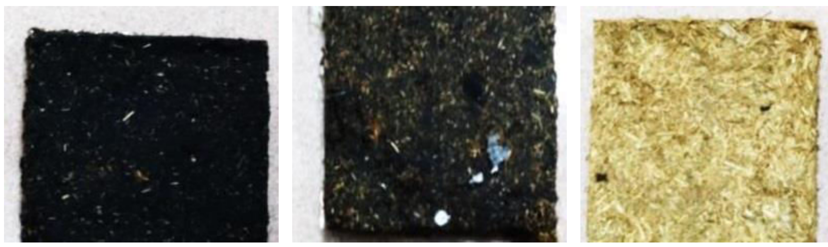
rubber tire dust (Sample 1). Then, continue with 50% by weight of sugarcane bagasse and rubber tire dust respectively (Sample 2) and 75 % of sugarcane bagasse and 25% by weight of rubber tire dust (Sample 3). Table-1 shows the mixing percentage of the composite of sugarcane bagasse and rubber tire dust as mentioned before.

Table-1. Mixing percentage of the composition of sugarcane bagasse with rubber tire dust.

Sample	Percentage (%)	
	Sugarcane bagasse	Rubber tire dust
Sample 1	25	75
Sample 2	50	50
Sample 3	75	25

The samples were fabricated in square shape and flat surface. The Polyester resin was used to bind the materials and MEKPO act as hardener agent. Then, all the samples were being measured using the dielectric probe technique. The open ended coaxial probe acts as cut off section of transmission line. The materials were being measured by touching the flat surface of the fabricated sample. The field at the probe end "fringe" into the material that contacted with the material (Iqbal *et al.*, 2014). Figure-1 below is the equipments that have been used to measure the dielectric properties of the sample which are the cylindrical and open ended coaxial probe with the calibration shorting block. Figure-2 shown below is the fabricated sample of sample 1, 2 and 3 in square shape.

Figure-1. The high temperature probe with the calibration shorting block.



Sample 1 Sample 2 Sample 3

Figure-2. The fabricated samples.

RESULT

The measured values of the dielectric constant (real part of complex permittivity) of the fabricated samples are greater than air (>1). This shows that the dielectric polarization of the materials can be polarized greater than air. Figure-3 shown below is the complex permittivity of sugarcane bagasse and rubber tire dust respectively in the range frequency of 2-8 GHz.

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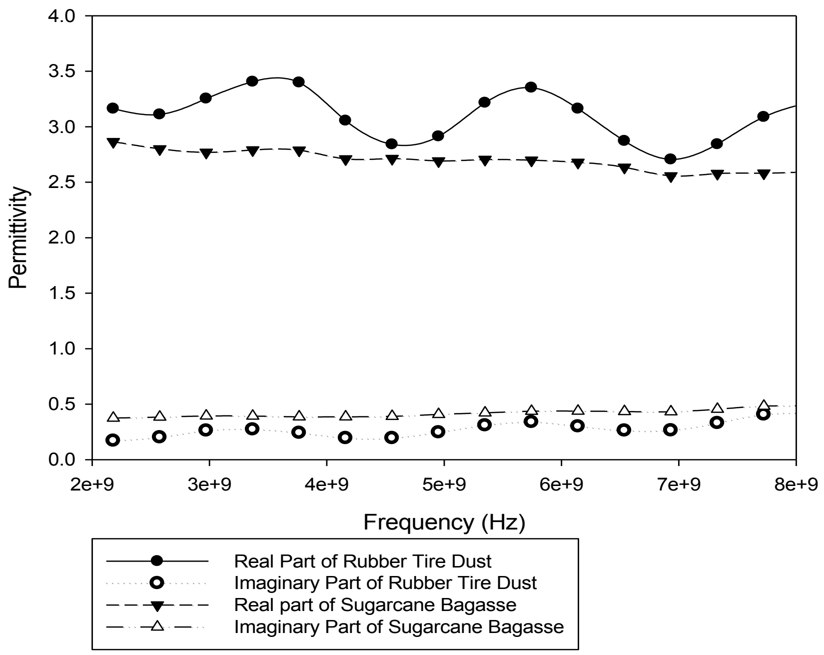

Figure-3. Complex permittivity of sugarcane bagasse and rubber tire dust in the range frequency of 2-8 GHz.

Table-2 shown below is the result of the measured dielectric properties of the two raw materials which are sugarcane bagasse and rubber tire dust in the range frequency of 2 - 8 GHz.

Table-2. Measured range of dielectric properties of the two raw materials which are sugarcane bagasse and rubber tire dust in range frequency between 2- 8 GHz.

Sample	Properties	2- 8 GHz
Sugarcane Bagasse	ε'	2.00 - 2.80
	ε"	0.30 - 0.50
Rubber Tire Dust	ε'	3.00 - 3.20
	ε"	0.10 - 0.40

The average dielectric constant (real part, ε') for the sugarcane bagasse for the frequency spectrum (2-8 GHz) was in the range between 2.00- 2.80. For rubber tire dust, the range of dielectric constant is 3.00 - 3.20 which is greater than the sugarcane bagasse. This is because of the component that contains in the rubber tire dust itself which is rubber. Rubber is a material that has a high dielectric constant value. Based on the figure above, we can see that the sugarcane bagasse has the higher loss factor (ε") ranging from 0.30 - 0.50 compared with the sample composed of rubber tire dust which is in the range between 0.10 - 0.40. Rubber tire dust has low dielectric loss and high dielectric constant. The high ε' indicated that the signal in rubber tire dust propagated at a slow speed due to large refractive index of the medium (Malek *et al.*, 2011).This will make the wavelength of the transmitted wave inside rubber tire dust material decrease faster than sugarcane bagasse. The sugarcane bagasse has low dielectric constant with high loss factor and this will lead to the large propagation constant (attenuation). Figure-4 shows the complex permittivity for sugarcane bagasse added with rubber tire dust with different composition (Sample 1, 2 and 3).

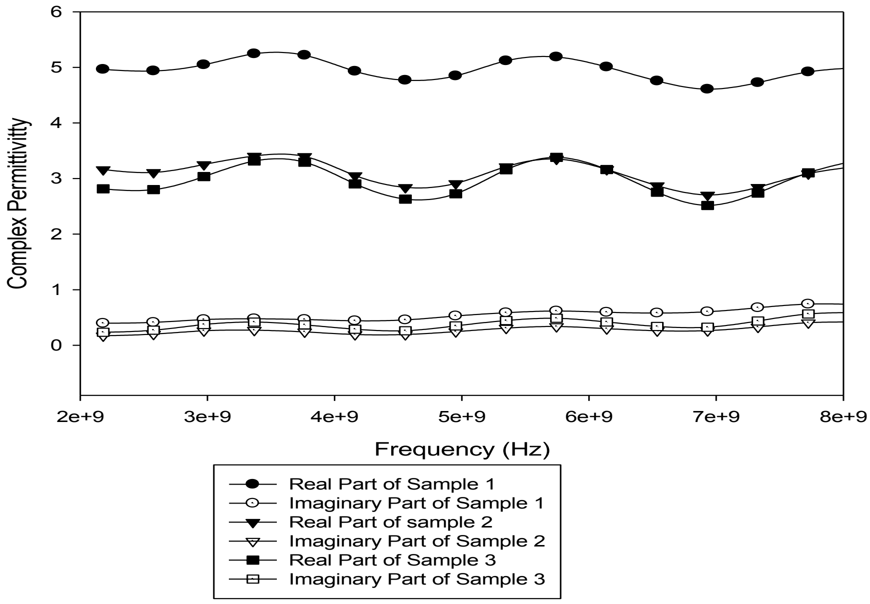

Figure-4. Complex Permittivity for sugarcane bagasse added with rubber tire dust with different composition.

Table-3 below shows the measured dielectric properties of three fabricated samples.

Table-3. Measured range of dielectric properties of the three fabricated samples in range frequency between 2- 8 GHz (Composition of Sugarcane Bagasse with rubber tire dust).

Sample	Properties	2-8 GHz
Sample 1 (25:75)	ε’	4.90 – 5.00
	ε”	0.30 – 0.70
Sample 2 (50:50)	ε’	2.80 – 3.40
	ε”	0.10 – 0.40
Sample 3 (75:25)	ε’	2.50 – 3.30
	ε”	0.20 – 0.60

CONCLUSIONS

The results of this experiment show that the sugarcane bagasse has low dielectric constant and high loss factor compare with rubber tire dust. As we know, in considering microwave absorption, the imaginary part which is ε” is crucial as it was related to the dissipation of microwave energy within material. Sugarcane bagasse can be an alternative material in designing the microwave absorber. There are many factors that affected the ε” such as the inhomogeneous mixing of chemical during fabrication. Besides, based on the result, the sugarcane bagasse and rubber tire dust can also be composited together to investigate and measure the performance as a microwave absorbing material as well.

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