Advanced Materials Research Vol. 893 (2014) pp 488-491
© (2014) Trans Tech Publications, Switzerland
doi:10.4028/www.scientific.net/AMR.893.488

Investigation on the Dielectric Properties of Pulverized Oil Palm Frond and Pineapple Leaf Fiber for X-Band Microwave Absorber Application

Elfarizanis Baharudin[1,5,a], Alyani Ismail[1,4,b], Adam Reda Hasan Alhawari[1,c], Edi Syams Zainudin[2,d], Dayang Laila Abang Abdul Majid[3,e] and Fauziahanim Che Seman[5,f]

[1]Department of Computer and Communication Systems Engineering, Faculty of Engineering,Universiti Putra Malaysia, Selangor, Malaysia
[2]Department of Mechanical and Manufacturing Engineering, Faculty of Engineering, Universiti Putra Malaysia, Selangor, Malaysia
[3]Department of Aerospace Engineering, Faculty of Engineering, Universiti Putra Malaysia, Selangor, Malaysia
[4]Institute of Advanced Technology, Universiti Putra Malaysia, Selangor, Malaysia
[5]Department of Communication Engineering, Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia, Johor, Malaysia

[a]elfarizanis@gmail.com, [b]alyani@upm.edu.my, [c]adamreda@upm.edu.my, [d]edisyam@upm.edu.my, [e]dlaila@upm.edu.my, [f]fauziahs@uthm.edu.my

Keywords: Permittivity, loss tangent, coaxial probe technique, dielectric mixture model, material density.

Abstract. This paper presents the results on dielectric properties of pulverized material based on agricultural waste namely oil palm frond and pineapple leaf fiber for microwave absorber application in the X-band frequency range. The investigation is started by identifying the pulverized materials permittivities and loss tangents using coaxial probe technique, followed by density measurement comprising the determination of bulk and solid densities. Then, by using dielectric mixture model the solid particle dielectric properties were determined. It is observed that the air properties give quite an effect on the permittivity and loss tangent of the pulverized materials. It is also found that the lower the material density the higher material dielectric constant will be. Furthermore, the results show that, both oil palm frond and pineapple leaf fiber are potential to be X-band absorber with average dielectric constant of 4.40 and 3.38 respectively. The loss tangents for both materials were observed to be more than 0.1 which mark them as lossy materials.

Introduction

The interest in microwave absorber has long existed and the demand for various kind of microwave absorber has increased due to their two fold use, electromagnetic interference and countermeasure for radar detection [1] particularly in the X-band application. The study on material characterizing for optimal microwave absorber has come into focus for many researcher where low density and wide bandwidth are partly important factors [2]. Transforming agricultural waste into microwave absorber has also become quite an attention. This is because, they are environmental friendly, cheap, abundantly avaiable,[3] and most importantly they have low densities.

This paper investigates the dielectric properties of agricultural waste involving two parametric properties, permittivity and loss tangent of pulverized material. The properties are realized by using coaxial probe technique, material density measurement and dielectric mixture model equation for X-band microwave absorber application.

Sample Preparation

Two types of agricultural waste which are abundantly available in the south peninsular Malaysia were selected. They were the oil palm frond (OPF) and pineapple leaf fiber (PALF). Each material was collected, cut into smaller pieces, weighted and oven dried at 105°C for 24 hour until a uniform weight was achieved. Then, the dried OPF and PALF were crushed and pulverized into 0.25 mm particle size. In this investigation, Rexolite 1422, was used as a reference material [4]. It was in a form of plate with thickness of 1.45 mm and it was broken into smaller pieces and also pulverized into 0.25 mm particle sized.

Experimental Set-up

Coaxial Probe Technique. In this investigation, each material permittivity was identified using coaxial probe technique. This method was easy, relatively cheap and can measure a broad range of frequency. A coaxial probe was placed on the surface of the pulverized material with volume thickness not less than 15 mm in a round container and then, an electric field was applied at room temperature. The signal was transmitted through, reflected and absorbed by the material. These conditions will result in the electrical properties of the material in terms of complex permittivity as in Eq. 1 and loss tangent as in Eq. 2 which is a measure of an absorption rate. Note that, the real permittivity, ε' is the dielectric constant and the imaginary permittivity, ε'' is the loss factor of the material.

$$\varepsilon^* = \varepsilon' - j\varepsilon'' \quad (1)$$

$$\tan\delta = \varepsilon''/\varepsilon' \quad (2)$$

Density Measurements. Low density material is one of the important factors in designing a good microwave absorber. In this investigation, bulk density of the pulverized materials were done by obtaining the material mass in a 3.5 cm^3 sample cell and divide it by the sample cell volume. Next, the solid material density was obtained by using an air-comparison pycnometer. Both bulk and solid densities are in the units of g/cm^3.

Dielectric Mixture Model

There many types of mixing model and Lichtenecker [5] is one of useful equations in determining the permittivity between two or more material constituents. In the case of pulverized material, air was the other constituent and therefore, the solid material permittivity can be determined. The Lichtenecker mixture model is given in Eq. 3. Since, the permittivity of air is $1 + j0$ and the volume of air with pulverized material is given by $v_1 + v_2 = 1$, hence, by reconstructing ε_2 in terms of fractional volume v_2 and ε, Lichtenecker model has now become Eq. 4 which is basically the permittivity of the solid pulverized material. The fractional volume can be obtained by dividing the material bulk density by the solid density.

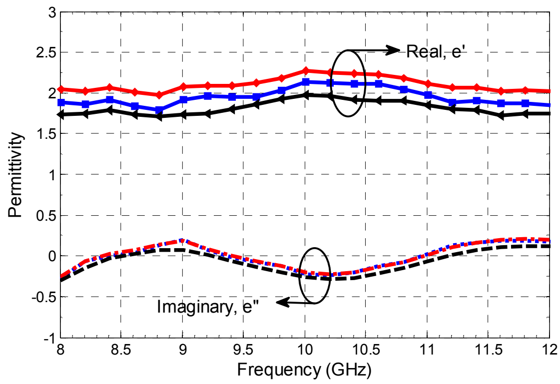
$$\ln(\varepsilon) = v_1 \ln(\varepsilon_1) + v_2 \ln(\varepsilon_2) \quad (3)$$

$$\varepsilon_2 = e^{((\ln \varepsilon)/v_2)} \quad (4)$$

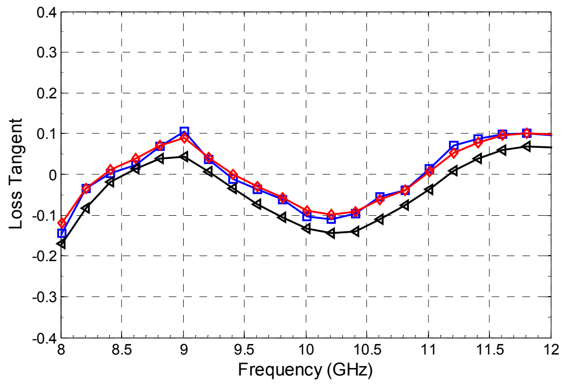
Result and Discussion

Coaxial Probe Technique. Fig. 1 (a) shows the permittivity variation for pulverized materials over the X-band frequency range obtained from coaxial probe measurements. It is observed that, Rexolite 1422 (Rex) has an average real permittivity value of 1.82. However, it does not match the dielectric constant of the solid form of Rex which is 2.53. This is for the fact that, when measuring pulverized material using coaxial probe technique, there are many air gaps in between the solid particles and hence, the air properties does effect the permittivity value of the pulverized material. It is also observed that, the average dielectric constant for OPF and PALF are 1.95 and 2.11 respectively and note that, these values are bounded by the presence of air.

The imaginary part of the permittivity is observed to fluctuate between positive and negative values from 8GHz to 12 GHz for all three pulverized materials as shown in Fig.1 (a). It is also similar to the loss tangent results in Fig.1 (b). This is because loss tangent has a direct relationship with material loss factor. When material loss factor is positive, the energy is being conserved due to damping of vibrating dipole moments, and when the loss factor is less than or equals to zero, the material is said to be lossless material at that particular frequency for which directly makes loss tangent zero as well.



(a)



(b)

Fig.1: Variation of (a) permittivities and (b) loss tangents for Rexolite 1422 (black), oil palm frond (blue) and pineapple leaf fiber (red) over frequency obtained using coaxial probe technique.

Material Density. Three pulverized materials were investigated for their bulk and solid densities. As shown in Table 1, OPF is observed to have lower fractional volume compared to PALF. This is because the fiber content for OPF is much lighter in contrast to PALF which gives slightly lower material density. The calculated fractional volume will be used to obtain the solid pulverized permittivity.

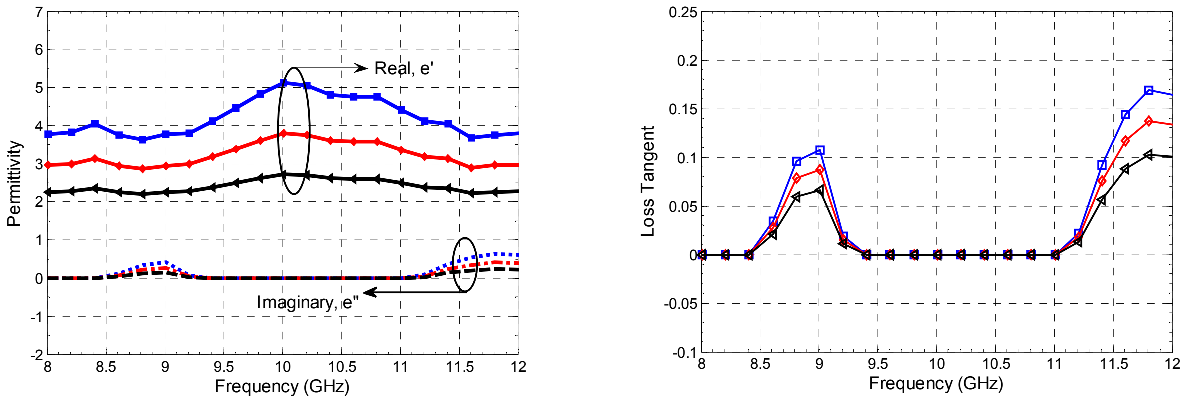
Table 1: Pulverized material densities.

Pulverized Material	Average Bulk Density,(g/cm^3)	Average Solid Density, (g/cm^3)	Fractional Volume, v_2
Rexolite 1422	0.5481	0.8103	0.6764
OPF	0.3593	0.8646	0.4155
PALF	0.4449	0.8743	0.5089

Lichtenecker Mixture Model. In this investigation, dielectric mixture model is used to determine the permittivity of solid pulverized material by applying the fractional volume calculated in Table 1 and the air-particle permittivity obtained in Fig. 1 (a) into Eq. 4. At this point, all negative loss factors are considered to be lossless at those particular frequencies.

Fig. 2 (a) shows the permittivity variations for three pulverized materials for frequency ranging from 8 GHz to 12 GHz. The average dielectric constant for Rexolite 1422 is 2.41 with percentage error of 4.74% in reference to the solid form of Rex. It is also observed that, the real permittivity curves of OPF and PALF show an average value of 4.19 and 3.22 respectively. Taking the percentage error for Rexolite 1422 as reference, the actual average dielectric constant for OPF and PALF are 4.40 and 3.38 respectively.

Based on the results for the material loss factor in Fig. 2 (a) the curves show that the energy was being conserved at two frequency bands which are between 8.41 GHz to 9.41 GHz and 11.01GHz to 12 GHz. In Fig. 2 (b), the loss tangents for OPF and PALF are observed to fall in the category of low loss dielectric for the frequency ranging from 8.41 GHz to 9.41 GHz where the loss tangent values are less than 0.01 [6]. It is also observed that at frequency between 11.01GHz to 12 GHz the loss tangent values of OPF and PALF can be grouped for lossy dielectric material since their values are more than 0.1 [6].



(a) (b)

Fig. 2: Variation of (a) permittivities and (b) loss tangents for Rexolite 1422 (black), oil palm frond (blue) and pineapple leaf fiber (red) over frequency obtained using Lichtenecker mixture model.

Summary

Two types of agricultural waste, oil palm frond and pineapple leaf fiber have been successfully investigated. The use of Rexolite 1422 as reference material helps to justify dielectric properties of OPF and PALF. Based on the findings, the coaxial probe technique is capable in providing the material permittivity and by removing the air constituent properties using the Lichtenecker mixture model, the solid pulverized material permittivity can be achieved. According to the results, it can be concluded that OPF and PALF are possible material for a microwave absorber where their dielectric constants are better than the natural dielectric material such as metal oxide, and semiconductors [6]. In addition, OPF and PALF are seen to have lossy material characteristic which makes them even more potential to be further investigated for microwave absorber specifically in the X-band application.

Acknowledgement

The author would like to thank Polymer and Ceramic Laboratory, Packaging Laboratory of Universiti Tun Hussein Onn Malaysia, Makmal Sifat Kejuruteraan Bahan Bio dan Neutraseutikal, INTROP of Universiti Putra Malaysia, especially to En. Selamat Bin Zaid, Haji Salleh Bin Romani and Radar Laboratory of Universiti Teknologi Malaysia for their help in this research work.

References

[1] S. M. Abbas, M. Chandra, A. Verma, R. Chatterjee, and T. C. Goel, “Complex permittivity and microwave absorption properties of a composite dielectric absorber,” vol. 37, pp. 2148–2154, 2006.

[2] R. Che, C. Wang, Y. Ni, and B. Yu, “Preparation and microwave absorbing properties of the core-nanoshell composite absorbers with the magnetic fly-ash hollow cenosphere as core,” *J. Environ. Sci.*, vol. 23, pp. S74–S77, Jun. 2011.

[3] U. G. Kispotta, “Synthesis and Characterization of Bio-Composite Material.”

[4] “Material Data Sheet REXOLITE ® 1422,” no. September, p. 2011, 2011.

[5] S. O. Nelson, “Density-Permittivity Relationships for Powdered and Granular Materials,” vol. 54, no. 5, pp. 2033–2040, 2005.

[6] Emerson & Cumming Microwave Product, “Dielectric Material Chart,” p. 5740.