Dielectric Properties of Rice Husk/Carbon Nanotubes Composites in Ku-band

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Abstract— This paper presents the dielectric properties of rice husk and carbon nanotubes (RHCNTs) composites materials. The RHCNTs composites materials prepared with various weight ratios of rice husk with CNTs 0–10 wt%. The length, width, and thickness of each RHCNTs composite sample are 15.799 mm, 7.899 mm, and 5 mm was fabricated. The rectangular waveguide technique was used to measure the complex relative permittivity of the RHCNTs composites materials. The conversion of *s*-parameters to complex relative permittivity parameter is computed by using 85071E Agilent technology software which using a transmission line technique consists of a network analyzer to perform the conversion to complex relative permittivity, ε_r. The complex relative permittivity is represented in terms of both the real and imaginary parts of permittivity in Ku-band frequency. The conductivity of RHCNTs shows increasing when the ratio of CNTs mixture increases. The materials, their dielectrics properties measurement result over 12.4–18 GHz frequency range are discussed.

1. INTRODUCTION

In recent years, rice husk (RH) is an agriculture waste material which potential used as microwave absorber been reported [1, 2]. Due to their complex permittivity, RH can design in pyramidal or flat microwave absorber [3–5]. Complex permittivity of a material is important parameter for microwave absorber application. The objective of this paper is to increase/enhance the complex permittivity of RH material by composites the RH with carbon nanotubes (CNTs). Recent years, CNT composites have potential applied in electronic, mechanical, and microwave application due to their unique properties [6, 7]. To form the composites, raw RH and CNTs were mixed with polyester and methyl-ketone-polymer. The RH was composite with difference amount of CNTs from 0% to 10% of weight ratio. The complex relative permittivity ($\varepsilon_r = \varepsilon'_r - j\varepsilon''_r$) of rice husk and carbon nanotubes composites (RHCNTs) is measured and investigated in Ku-band. The real part of complex permittivity is the ability of a material to store electromagnetic wave, whereas the imaginary part of the complex permittivity is the ability of the material convert the electromagnetic wave into heat and dissipated. Furthermore, the alternative current (AC) conductivity can calculate by using Equation (1) [8]:

$$\sigma_{ac} = \omega\varepsilon_0\varepsilon''_r \tag{1}$$

where, σ_{ac} is the conductivity due to the alternating field (S/m), ω is the angular frequency (rad/s), ε_0 is the permittivity in free space, ε''_r is the imaginary part of relative complex permittivity (loss factor).

2. PREPARATION OF SAMPLES

First, the rice husk and CNTs were mix with polyester resin and methyl ethyl ketone peroxide (MEKP) harden agent. The RHCNTs composites were stir for 1 hour shown in Figure 1. After the composition, the RHCNTs composite were filled into waveguide sample holder to fabricate the rectangular shape sample for WR-62 waveguide. The RHCNTs samples were fabricated by using WR-62 sample holder mould shown in Figure 2. The RHCNTs samples were prepared in rectangular shapes, which fit into WR-62 waveguide sample holders.

Figure 1: RHCNTs after stir with polyester and MEKP.

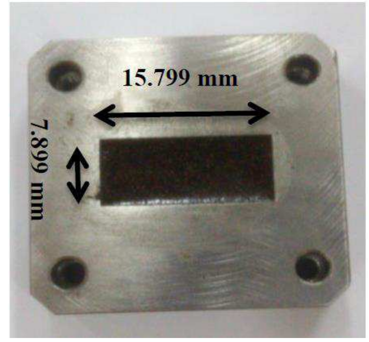

Figure 2: Ku-Band sample holder fit with RHCNTs sample.

3. EXPERIMENTAL

Before conduct to the measurement, calibration technique TRL (through-reflect-line) of waveguide flanges must be applied. The calibration technique is to minimize the residual errors of the measurements. The Dielectric properties were measured using rectangular waveguide transmission line technique. A pair of coaxial cable was connected to Agilent E8362B performance network analyzer and the two waveguide adaptors were connected with coaxial cables. The sample holder was place between the two waveguide adaptors. The 85071E software is originally developed by NRW to calculate the permittivity from transmission and reflection coefficient [9]. Figure 2 shows the dielectric measurement setup.

4. RESULTS AND DISCCUSION

The complex relative permittivity of samples versus frequency was shown in Figures 3(a) and (b). The complex relative permittivity of real part (dielectric constant, ε_r') and imaginary part (loss factor, ε_r'') of the composites increased over the measured frequency region with increasing the quantity percentage of CNTs. For rice husk, the average values of ε_r' and ε_r'' were 2.982 and 0.283 respectively. The RH-CNTs2%, RH-CNTs4%, and RH-CNTs10% samples has the average values of ε_r' was 5.448, 6.443, and 14.972 respectively. The average values of ε_r'' was increases from 0.283 (rice husk) to 8.492 (RH-CNTs10%). By increasing the quantity of CNTs in RHCNTs composites can enhance complex relative permittivity of the composites materials.

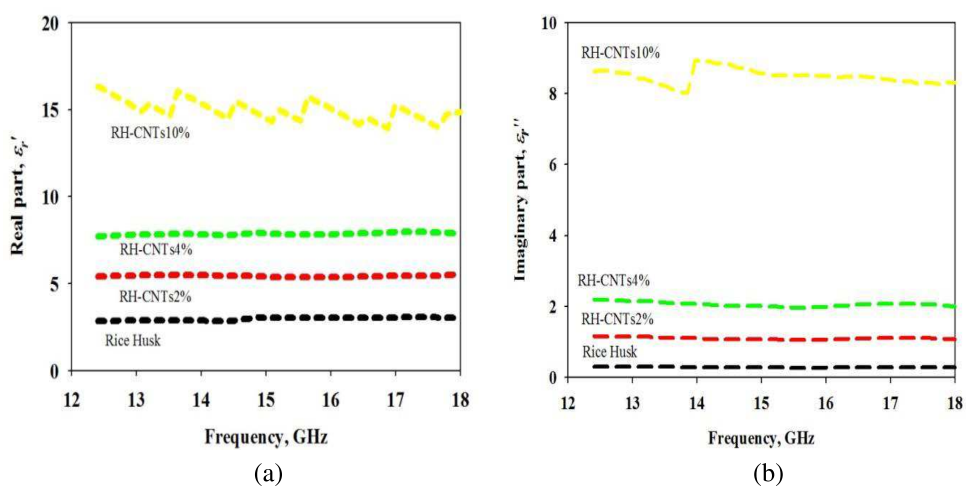

Figure 3: (a) Real part and (b) imaginary part of complex relative permittivity of samples.

Figure 4 shows the conductivity of samples. From the graph, RH-CNTs10% sample has the highest conductivity (580–800) S/cm than rice husk, RH-CNTs2%, and RH-CNTs4%. The conductivity of the RHCNTs composites is increasing when the content of CNTs increases in the RHCNTs composition. Refer to the Equation (1), the conductivity is proportional to the imaginary of complex

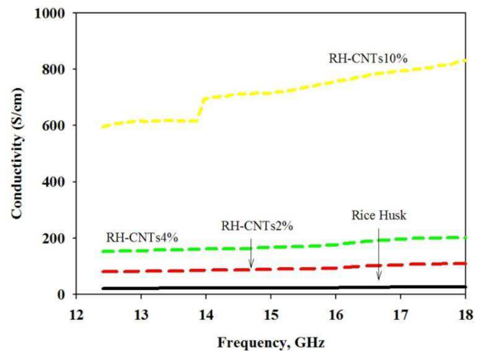

Figure 4: Conductivity of RHCNTs samples.

relative permittivity and frequency. Therefore, increase the quantity of CNTs in the RHCNTs composites, ε_r'' increased and the conductivity of the RHCNTs composites also increased. The average values conductivity of rice husk, RH-CNTs2%, RH-CNTs4%, and RH-CNTs10% samples were 24, 93, 174, and 717 S/cm respectively. The average values of dielectric constant, ε_r', loss factor, ε_r'', and conductivity, σ_{ac} are shown in Table 1.

Table 1: Average values of ε_r', ε_r'', and σ_{ac}.

Sample	Average values		
	Dielectric constant, ε_r'	Loss factor, ε_r''	Conductivity, (S/cm)
RH	2.982	0.283	24
RH-CNT2%	5.448	1.100	93
RH-CNT4%	6.443	1.584	174
RH-CNT10%	14.972	8.492	717

5. CONCLUSIONS

The complex relative permittivity of rice husk successful enhanced with composites rice husk with carbon nanotubes. The RHCNTs was increased up to 14.972 of dielectric constant and 8.492 of loss factor with composites with 10% CNTs. The conductivity of RHCNTs also increased from 24 S/cm (rice husk) up to 717 S/cm (RH-CNTs10%) over 12.4–18 GHz frequency range. Hence, the RHCNTs samples are suitable to apply in dielectric microwave absorber and shielding materials due to their complex permittivity and conductivity performance.

ACKNOWLEDGMENT

The authors acknowledge the University Malaysia Perlis and the Malaysian Ministry of Higher Education for providing the Fundamental Research Grant Scheme (FRGS Grant No. 9011-00011), which enabled the publication of this article.

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