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Shielding Effectiveness of Rice Husk and CNT Composites in X-Band Frequency

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***Abstract*—**This paper presents the electromagnetic interference (EMI) shielding effectiveness of rice husk and carbon nanotubes (RHCNTs) composites in the X-band region (8.2-12.4 GHz). The difference weight ratio of carbon nanotubes (CNTs) were mix with the rice husk. The rectangular waveguide technique was used to measure the complex permittivity of the RHCNTs composites materials. The complex permittivity is represented in terms of both the real and imaginary parts of permittivity in X-band frequency. The conductivity of RHCNTs shows increasing when the ratio of CNTs mixture increases. The composites materials were simulated using Computer Simulation Technology (CST) Microwave Studio simulation software. The shielding effectiveness of RHCNTs and pure rice husk was compared. The highest EMI SE of 30 dB is obtained for RHCNTs composites of 10 wt % CNTs with 10mm thickness.

***Keywords*—**EMI Shielding effectiveness, Carbon nanotube, Composite materials, Waveguide, X-band.

I. Introduction

MICROWAVE absorbing materials (MAM) have various applications such as communications, radar, and anechoic chambers [1], [2]. Some of the MAM have different ability of absorption in microwave signal due to different dielectric properties. The dielectric properties of materials at microwave frequency have gained increasing importance in research field such as absorber development, material science, etc. Dielectric consists of real part, ε' and imaginary part, ε". The real part of dielectric properties is a measure amount of energy from an electrical field stored in the material, known as dielectric constant [3], [4]. The imaginary part is also known as loss factor which is a measure of the amount of energy loss from the material [5], [6]. The loss tangent represents the ratio of the loss factor to the dielectric constant of the dielectric properties.

Equation (1) is the relationship of between loss tangent, loss factor, and dielectric constant [7].

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$$\tan \delta = \frac{\varepsilon''}{\varepsilon'} \qquad (1)$$

II. Sample Preparation

The RHCNTs composites materials prepared with various weight ratios of rice husk (RH) with CNTs 1%-10%. The mixture ratio of RHCNTs samples are shown in Table I. The length, width, and thickness of each RHCNTs composite sample are 22.860 mm, 10.160 mm, and 5 mm was fabricated.

TABLE I
Mixture Ratio of Rice Husk/Carbon nanotubes (%Total Weight)

Rice Husk (%)	Carbon nanotube (%)	Samples size (length x width), mm
100	0	22.860 x 10.160
99	1	22.860 x 10.160
95	5	22.860 x 10.160
90	10	22.860 x 10.160

First, the rice husk and CNTs were mix with polyester resin and stir the mixture for 30 minutes. Then, mix with the methyl ethyl ketone peroxide (MEKP) harden agent to harden the sample. The mixture after stir for 30 minutes was shown in Fig. 1.

Fig. 1 Mixture RHCNTs with resin and MEKP

After the composition, the RHCNTs composite were filled into waveguide sample holder to fabricate the rectangular shape sample for WR90 waveguide. The RHCNTs samples were fabricated by using WR 90 sample holder mould shown in Fig. 2 (a). The RHCNTs samples were prepared in rectangular shapes, which fit into WR-90 waveguide sample holders. Fig. 2 (b) shows the fabricated RHCNTs samples.

Fig. 2 (a) X-Band sample holder and RHCNTs sample

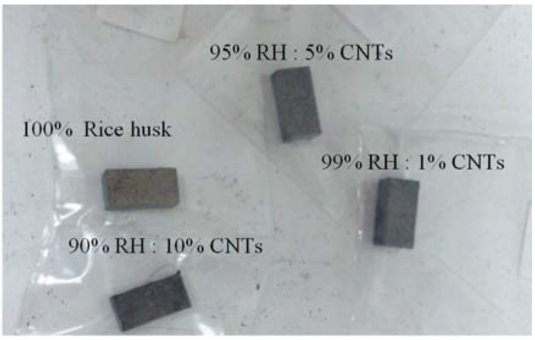

Fig. 2 (b) Fabricated RHCNTs samples

III. Dielectric Properties Measurement

Before conduct to the measurement, calibration technique TRL (through-reflect-line) of waveguide flanges must be applied before conduct the measurement. The calibration technique is to minimize the residual errors of the measurements. The complex permittivity was 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 conversion of s-parameters to complex dielectric 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 permittivity, ε_r. The 85071E software is originally developed by NRW to calculate the permittivity from transmission and reflection coefficient [8]. The materials, their dielectrics properties measurement result over 8.2-12.4GHz frequency range are discussed.

IV. Simulation

The complex permittivity of the RHCNTs materials is the basic parameters which effect the reflection and transmission through medium. The data of complex permittivity of composites material was define and substitute in CST microwave studio. The result of SE of RHCNTs materials was simulated using Computer Simulation Technology (CST) Microwave Studio software. The dimension of the RHCNTs samples were shown in Fig. 3. Fig. 4 shows the RHCNTs composite samples fit into rectangular waveguide in CST software. In simulation, the dimension of the rectangular waveguide are playing important role in determining which frequency the rectangular waveguide to operate [9]. In simulation, the cutoff frequency is 6.56 GHz similar as X-band (WR-90) waveguide data sheet. The SE result of different RHCNTs composite samples obtain from CST simulation was investigated.

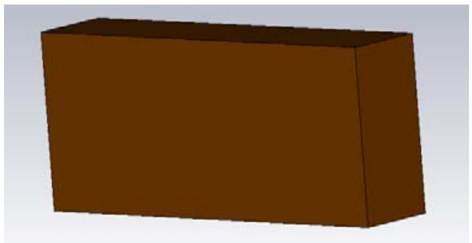

Fig. 3 Dimension of RHCNTs samples in CST

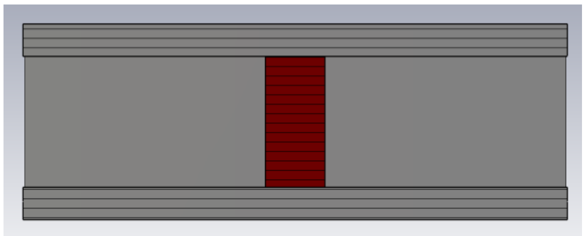

Fig. 4 RHCNTs sample fit into rectangular waveguide

In this simulation, the RHCNTs samples were simulated as waveguide transmission line. Port 2, S_{21} shows the result of electromagnetic wave transmitted through the material. If the RHCNTs samples do not act as shielding materials, the entire signal either is transmitted through the material.

V. Theory

In EMI shielding effectiveness is defined in terms of the ratio of the of the incident and transmission waves [10]. The shielding effectiveness formula is:

$$SE = 10 \log (E_i/E_t) \quad (2)$$

where Ei and Et are the powers of the incident and transmission waves, respectively. The unit of the EMI shielding effectiveness is the decibel (dB).

In most cases, Microwave absorbers that involve dielectric loss are electrically conductive[11]. The electrical conductivity, σ (in S/m), of a material under AC due to the alternating field is assessed using imaginary part of the relative permittivity obtained in frequency range using the following formula [12], [13]:

$$\sigma_{ac} = \omega \varepsilon_0 \varepsilon_r'' \quad (3)$$

where, $\sigma_{ac}$is the conductivity due to the alternating field (S/m), ω is the angular frequency (rad/s), and ε_r" is the imaginary part of the absolute relative permittivity. σ_{ac} is proportional to frequency and the loss factor, ε_r'' decreases when the frequency increases because effect of conductivity.

VI. Results and Discussion

The real part (dielectric constant) and Imaginary part (loss factor) of complex permittivity measurement results for RHCNTs samples over frequency range 8.2 – 12.4 GHz are presented in Figs. 5 and 6. In the frequency range, the dielectric properties of RHCNTs are increasing with increases of amount CNTs in ratio RHCNTs composites. When 1% CNTs mix with the rice husk, the dielectric constant is increase roughly values 2 but loss factor just slightly increase 0.2-0.3 compare to pure rice husk. For samples with 10% CNTs, the dielectric constant value is 16.5-19 and loss factor is 8-9 value. Figs. 5 and 6 show that increasing the ratio of CNT in the composite with rice husk which can increase the complex permittivity of the samples.

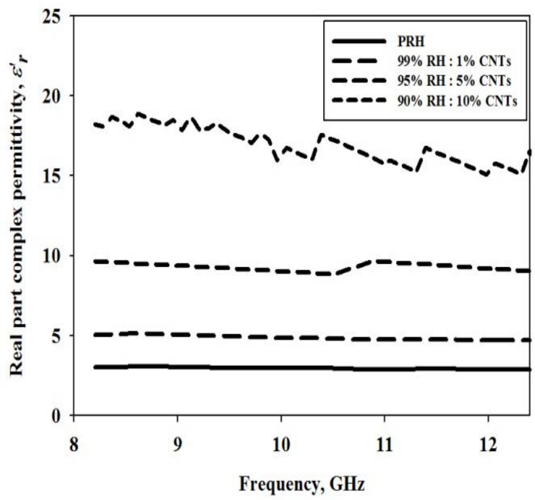

Fig. 5 Real Part complex permittivity, ε_r'

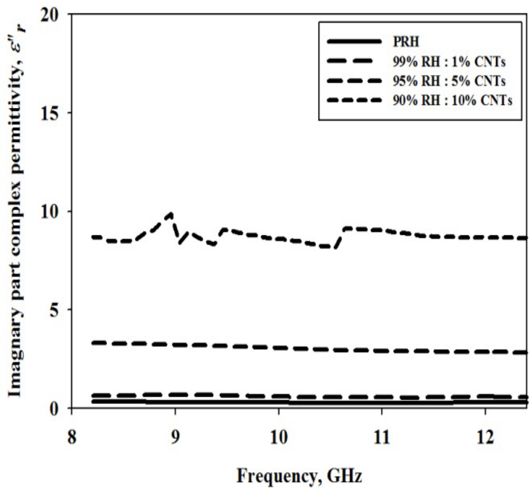

Fig. 6 Real Part complex permittivity, ε_r''

The RHCNTs samples electrical conductivity over 8.2-12.4 GHz frequency range has been achieved using the $\sigma_{ac} = \omega\varepsilon_0\varepsilon_r''$ formula and the calculated conductivity results are shown in Fig. 7. The result shows 90% RH: 10% CNTs sample has a high conductivity with highest values between 8.2-12.4 GHz and pure rice husk (PRH) sample has lowest values of conductivity over 8.2-12.4 GHz frequency. Fig. 7 shows that with the increase of the content of CNTs electric conductivity gradually increase, and with the increase of the frequency. Due to the content of carbon tubes increase in the RHCNTs composite, the dielectric conductivity of RHCNTs composite increase whereas carbon is a conductive material. The conductivity of dielectric material is proportional to the frequency (3).

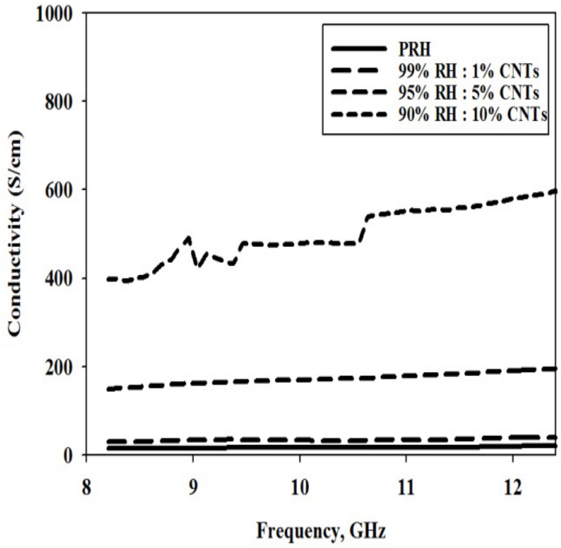

Fig. 7 Conductivity of samples

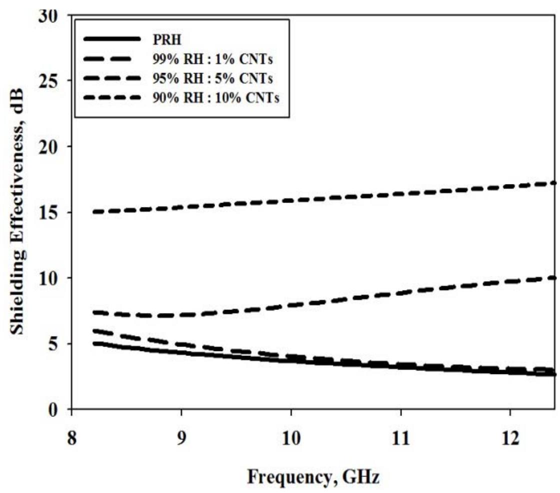

Fig. 8 SE of different RHCNTs samples

From Fig. 8, the EMI SE result of RHCNTs composites with 5mm thickness was simulated in X-band. The EMI SE of RHCNTs samples were increasing as the ratio of CNTs in

RHCNTs increased. The EMI SE of PRH sample 90% RH: 10% CNTs show 2.65 dB and 17.23 dB at 12.4 GHz. The EMI SE between the two samples almost increases 14.58 dB at 12.4 GHz. Table II shows the result of average SE of pure rice husk and various RHCNTs composites with thickness 5 mm over 8.2-12.4GHz frequency range.

TABLE II
AVERAGE SHIELDING EFFECTIVENESS OF RHCNTS SAMPLES

Materials	Average Shielding Effectiveness, dB
Pure rice husk	-3.63
99% RH : 1% CNTs	-4.04
95% RH : 5% CNTs	-8.31
90% RH : 10% CNTs	-16.05

Fig. 9 shows SE of 90% RH : 10% CNTs samples are increasing when the thickness of sample increases from 2mm-10mm. Due to the thickness of SE materials, thicker sample can block more electromagnetic wave compare to the thin sample. The SE sample is thicker which can cause the electromagnetic wave more difficult to propagate through the materials.

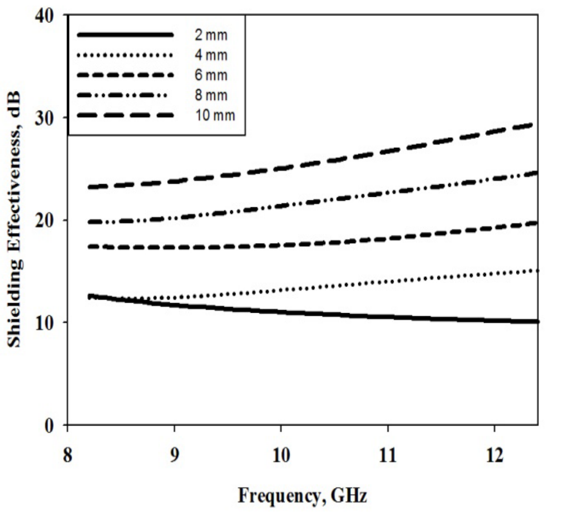

Fig. 9 SE of 90% RH:10% CNTs sample with 2-10mm thickness

The average SE of 90% RH: 10% CNTs sample are shown in Table III. RHCNTs samples with 2mm thickness has the lowest average SE value 11.02 dB and highest average SE value is -25.79dB RHCNTs samples with 10mm thickness.

TABLE III
AVERAGE SHIELDING EFFECTIVENESS OF 90% RH: 10% CNTS SAMPLES

Thickness	Average Shielding Effectiveness, dB
2mm	-11.02
4mm	-13.50
6mm	-18.01
8mm	-21.86
10mm	-25.79

VII. CONCLUSION

Rice husk and carbon nanotubes are new composites materials and dielectric lossy materials which potential use as shielding effectiveness materials. The CNTs shows the improved the complex permittivity and conductivity of the RHCNTs composites. It is obvious shows that the values of EMI SE increased in simulated frequency as the amount percentage of CNTs in RHCNTs increased. The results show that RHCNTs composite with CNTs 10% has excellent EMI shielding ability with SE higher than 15 dB in simulated frequency range. The 90% RH:10% CNTs sample with 10mm has average shielding effectiveness 25.79 dB.

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