Jurnal Mekanikal
June 2005, No. 19, 1 – 10

EFFECT OF OIL PALM SHELL CARBON-POLYESTER RESIN COMPOSITE ON MICROWAVE ABSORBER PROPERTIES

Farid Nasir Ani[1],
Wan Khairuddin Wan Ali[1]
Ahmad Anas Yusof[2]

Fakulti Kejuruteraan Mekanikal
Universiti Teknologi Malaysia
81310 UTM Skudai Johor D.T.
Malaysia

ABSTRACT

Pyrolysis effect on the dielectric properties of microwave absorber composed of palm shell carbon-polyester resin composite was studied. The permittivity, ε, and loss tangent, tan δ of the composite were studied in the 8 to 12 GHz frequency range which emphasize the influence of carbon concentration (mass %) of pyrolysed oil palm shell carbon at 600°C, 700°C and 800°C. It was observed that the increase of carbon concentration inside each measured composite influenced the increase of ε and tan δ condition. This indicates the possibility of using carbon derived from oil palm shell residue in providing significant loss in contributing to microwave absorption, as well as an alternative in managing the increase of oil palm shell residues throughout the country.

Keywords: *Composite, Microwave Absorber, Dielectric Properties, Waste Utilization*

1.0 INTRODUCTION

Malaysian Oil palm plantation has seen unprecedented growth in the last four decades to emerge as the leading agricultural industry in the country. Beside oil production for domestic and industrial use, the biomass has produced a wide range of utilization in residue and value added by-products. The needs to reduce oil palm residues become increasingly important throughout the years [1].

Recent studies had shown that oil palm residuals such as trunks, shells and fibers could be recycled into useful material for other practical applications. Studies proved that palm fibers can be use to produce medium density fiberboard [2]. Others have produced paper from chopped palm trunk [3]. The shells, which are finally turned into leftover slag from mill boilers, have been studied for a possible element in tarring roads. Besides being cracked into oil and resins, the

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[1] Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Johor.

[2] Faculty of Mechanical Engineering, Kolej Universiti Teknikal Kebangsaan Malaysia. Locked Bag 1200, Ayer Keroh, 75450 Melaka, Malaysia

final product of recycled palm shell residuals is in the form of charcoal or carbon [4 - 6].

The pyrolysed carbon from palm shell residue had been used as filler in producing conductive composite using polyester resin. In general, conductive composite can be made by filling non-conductive material with conducting particles such as carbon, metal flake, fibers and powder [7 - 9]. The conductivity of the composite usually provided by the carbon, while the function of the non-conductive material is to hold the material together in one piece. [10 - 11].

One of the potential applications of the composite studied is the application in microwave absorption [12 - 13]. Microwave absorber had implemented the use of carbon as a dissipative element, which transformed incoming wave into heat. This principle requires the material to be in a lossy or high loss condition, which can be represented by the high value of $\tan \delta$. Previous studies had developed such absorber using carbon of various origin integrated with non conductive material such as rubber, polyurethane and polypropylene. The studies also associate the use of such material in military applications such as radar absorber, electrical insulation and electromagnetic interference reduction [14 - 18].

2.0 SAMPLE PREPARATION AND EXPERIMENTATION

The oil palm shells, which were the raw material in producing the carbon, were obtained from Federal Land Development Authority (FELDA) Palm Oil Mills in Kulai, Johor. Figure 1 illustrates the preparation of the composite by grinding and sieving the dried palm shell residue into fine particles. Particle size was set at maximum size of 75 μm, using BS 410 stainless steel mesh wire. The use of fine particles can cause better mixture in the composite concentration and increase the particle contact inside the host in promoting optimum conductivity.

This was followed by drying palm shell residues in the Memmert 200 oven for about 24 hours to eliminate moisture content that might influence the carbon yields in the process. Initial weight for the palm shell was set at 120 grams before placing inside a fluidized bed combustor, in which the transformation of palm shells into carbon powder was carried out. It used nitrogen as the inert gas during pyrolysis. The pyrolysis or carbonization process started with constant nitrogen gas flow of 1.5 liter/min and let alone for one hour. The pyrolysis (carbonization) temperature for palm shell residues were set at 600°C, 700°C and 800°C, with heating rate of 10°C per minute. The surface area of the carbon was later characterized using nitrogen adsorption analysis from Micromeritic ASAP 2010. The results show that pyrolysed carbon at 600°C, 700°C and 800°C had resulted in a surface area of 159.4 m^2/g, 184.5 m^2/g and 195.53 m^2/g respectively.

The palm shell carbons were later mixed with unsaturated polyester resin as the matrix. Using different levels of concentrations and pyrolysis temperature as shown in Table 1, the samples were prepared by mixing the pyrolysed carbon and resin thoroughly before dispensing them into selected mould. The process involved the adding up of 3% peroxide catalyst known as MEKP (Methyl Ethyl Ketone Peroxide) in order to accelerate the curing process. This created possible condition for the mixture to be hardened at room temperature for about 3 hours.

The composites were dried in a furnace with temperature up to 150°C for complete hardening. They were later mechanically shaped and precisely cut into blocks of 22.86 x 10.16 x 5 mm in dimension according to the required test.

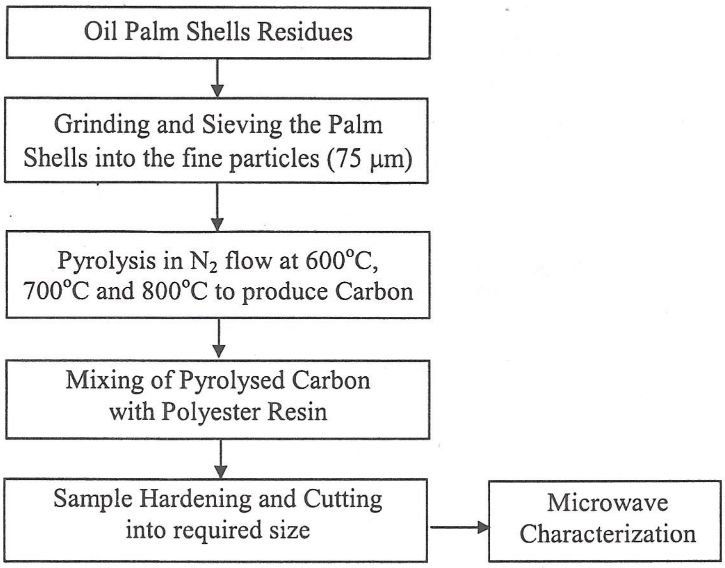

Figure 1: Sample preparation of utilizing palm shell carbon into microwave absorber

The composites were tested for microwave properties with IFR Microwave System Analyzer and a rectangular WR-90 waveguide operating from 8 to 12 GHz frequency range (X-Band) as shown in Figure 2. The signal source output from the integral spectrum analyzer had been used to provide signals with the same frequency during the measurement. The reflected signals was analyzed by the spectrum analyzer, which were the measured parameters and were later calculated to acquire the value of ε and tan δ.

Table 1: Samples preparation based on pyrolysis temperature (°C) and carbon concentration (%)

Pyrolysis Temperature (°C) of Carbon	Concentration (mass %)	
	Carbon Particles	Unsaturated Polyester Resin
600, 700 and 800	5.0	95
	10	90
	15	85
	20	80
	25	75
	30	70

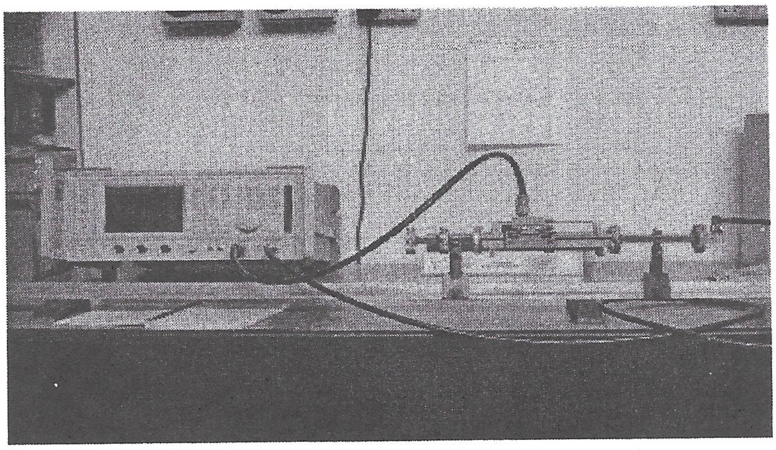

Figure 2: Microwave characterization using waveguide transmission line setup

3.0 RESULT AND DISCUSSION

3.1 Pyrolysis Effect on Microwave Properties at 600°C

The effect of mixing pyrolysed palm shell carbon at 600°C with unsaturated polyester resin at different concentrations (%) was investigated. Figure 3 shows an increase in ε'_r with respect to increased carbon concentration (%) inside each composite throughout the X-band frequencies. The dependence of ε'_r with respect to the carbon loading of the composite showed that pyrolysed carbon at 600°C influenced significant changes in the microwave properties of the material.

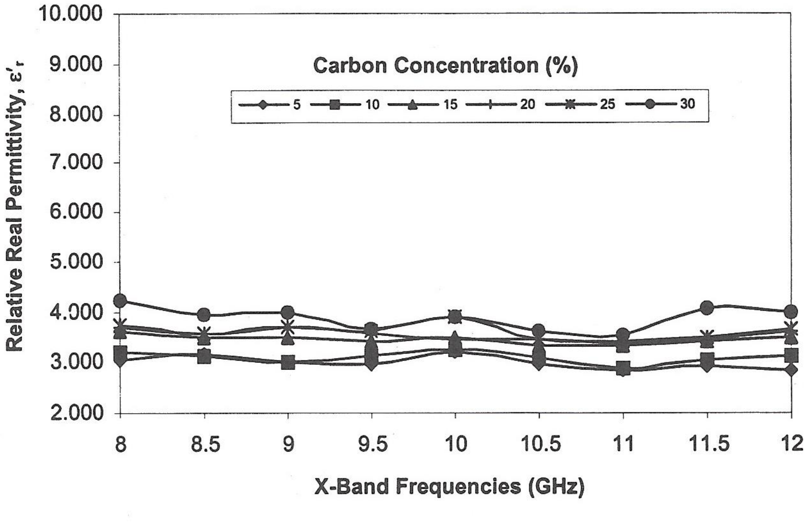

Figure 3: Relative real permittivity ε'_r at different carbon concentrations (%) in X-Band frequencies. (Pyrolysed carbon of 600°C)

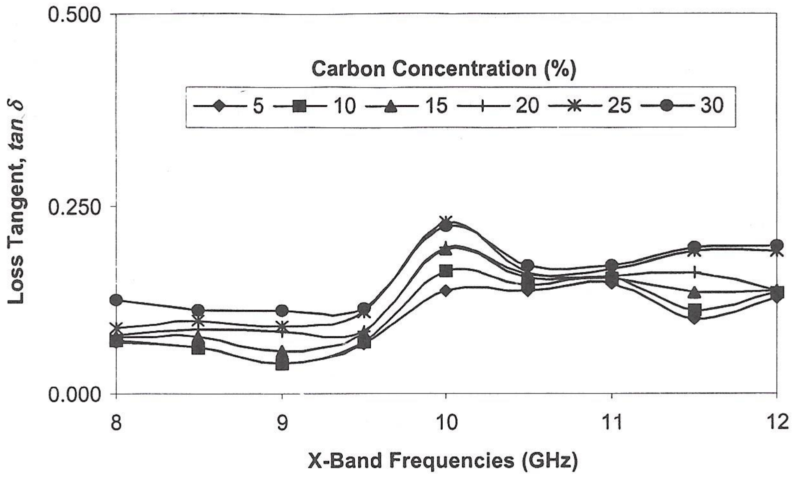

Figure 4: Loss tangent, *tan δ* at different carbon concentrations (%) in X-Band frequencies. (Pyrolysed carbon of 600°C)

The lossy condition could be observed in Figure 4, where increased *tan δ* could be observed with the increase of carbon concentrations. A similar pattern of dielectric loss can be observed in every concentration, with maximum loss obtained at 10 GHz in nearly all concentrations. The small difference in between each concentration however suggested that carbon produced at 600°C has a limitation effect over the lossy condition of the mixture.

3.2 Pyrolysis Effect on Microwave Properties at 700°C

Microwave properties of polyester resin mixed with pyrolysed palm shell carbon at 700°C had illustrated significant increase of ε'_r and *tan δ* with respect to the increase of carbon concentrations (%). Figures 5 and 6 showed the results of ε'_r and *tan δ* based on composites by using pyrolysed palm shell carbon at 700°C.

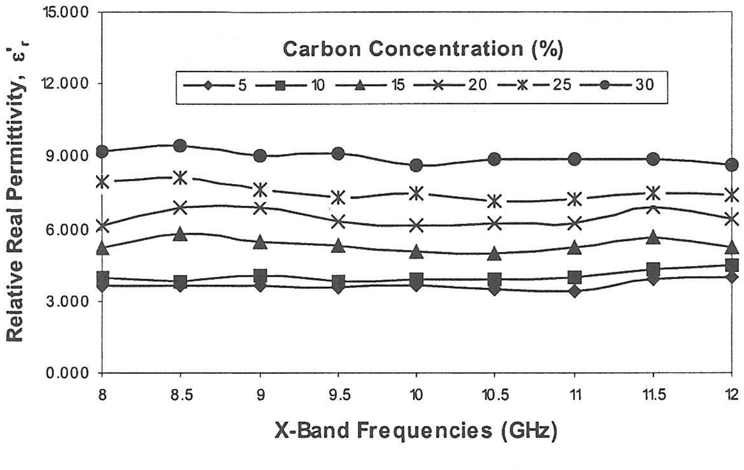

Figure 5: Relative real permittivity ε'_r at different carbon concentrations (%) in X-Band frequencies. (Pyrolysed carbon of 700°C)

The sample showed higher value of ε'_r and *tan* δ with respect to the composites prepared using pyrolysed palm shell carbon prepared at 600°C. In this case, the utilization of pyrolysed carbon at 700°C in polyester resin had resulted in a better increase in the microwave properties of the composites.

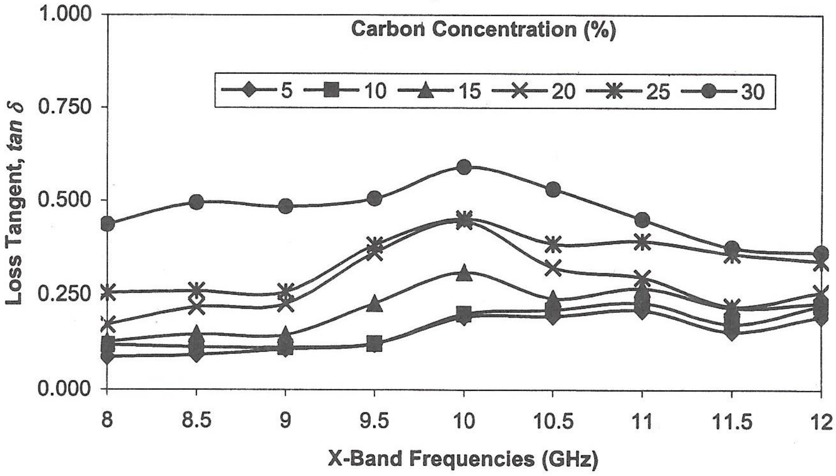

Figure 6: Loss tangent, *tan* δ at different carbon concentrations (%) in X-Band frequencies (Pyrolysed carbon of 700°C)

Significant *tan* δ could be observed in Figure 6 to be increasing from 5% to 30% concentration across the chart. At 8 GHz, carbon loading of 5% concentration showed minimum *tan* δ while maximum *tan* δ was observed at 10 GHz in 30% concentration. Figure 6 also showed abrupt increase in the *tan* δ in 30% concentration with respect to the other concentration, suggesting the influence of conductivity in the composite loss represented by *tan* δ for the same concentration.

3.3 Microwave Properties for Pyrolysis at 800°C

Figures 7 and 8 illustrate a higher increase in ε'_r and *tan* δ with respect to the increase of carbon concentrations (%) using carbon pyrolysed at 800°C. The results also substantiated better increments of ε'_r and *tan* δ over other polyester resin which was mixed with carbon pyrolysed at 600°C and 700°C.

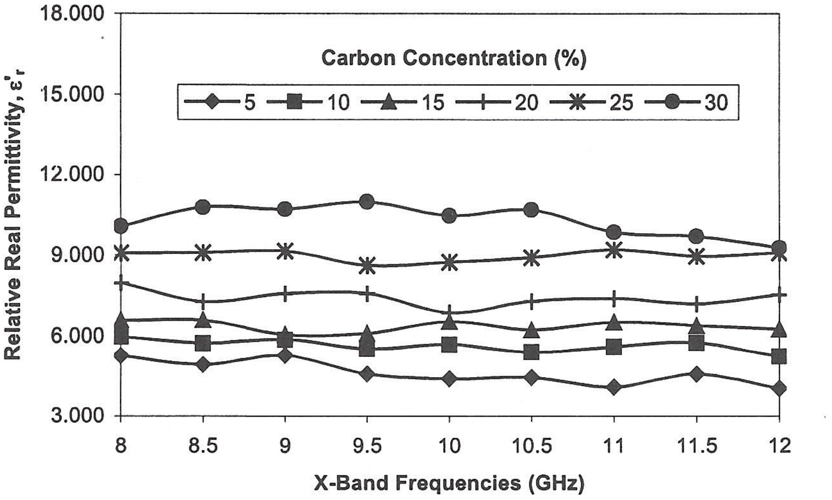

Figure 7 : Relative real permittivity ε'_r at different carbon concentrations (%) in X-Band frequencies. (Pyrolysed carbon of 800°C)

Figure 8 showed increasing trends of losses from *tan* δ of 5% concentration, up to a maximum loss condition at 30% carbon concentration. It showed that the maximum *tan* δ occurs at 10 GHz in polyester resin mixed with 30 % carbon concentration while minimum *tan* δ is observed in 5% carbon concentration at 8.5 GHz. It also showed a decreasing trend of *tan* δ starting from 11.5 GHz onwards The same trend can be seen in mixed resin with pyrolysed carbon at 700°C and this phenomenon is currently being investigated.

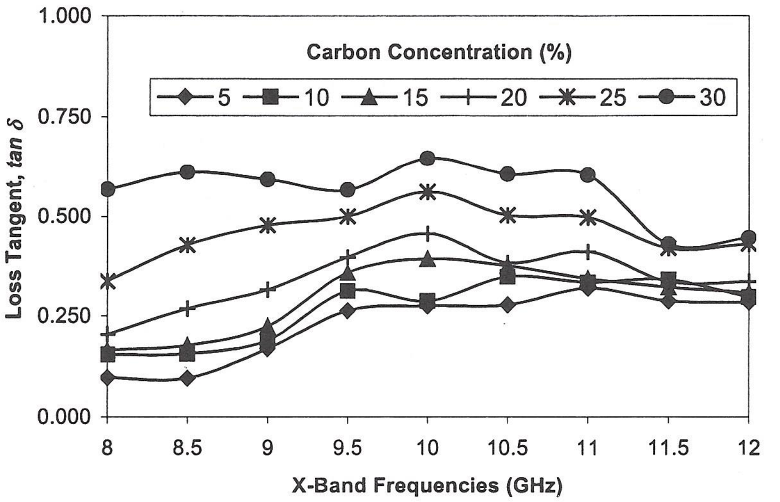

Figure 8 : Loss tangent, *tan* δ at different carbon concentrations (%) in X-Band frequencies. (Pyrolysed carbon of 800°C)

The highest dielectric loss of polyester resin with 30% carbon loading concluded that increased carbon loading helps in accumulating better loss in microwave absorber. The results also suggest that measurement at high frequency range had influenced the measured *tan δ*. In this case, the imaginary permittivity, which contributed to the lossy condition of the composite, started to decrease.

4.0 CONCLUSION

The effects of pyrolysis temperature on microwave properties in the X-band region using conducting composites from palm shell carbon-loaded polyester composite were studied. Three type of pyrolysed carbon, each at 600°C, 700°C and 800°C were measured with various mass concentrations from 5% up to 30% carbon loading. The change in the conductivity is a consequence of the formation of a continuous conducting network throughout the polymer matrix. The critical concentration at which the sudden increase in conductivity level was observed for composite utilizing palm shell carbon at 700°C and 800°C, the values being around 20% and 15% respectively. The ε and tan δ increased with the increase in palm shell carbon concentration.

The composite that utilized palm shell carbon of 800°C showed better loss than palm shell carbon pyrolysed at 700°C. The maximum dielectric loss was slightly over 0.5 by the 30% loading in the composites. Pyrolysis temperature was observed to be influencing the increase of ε and tan δ in each composite. This can be seen by the higher value of microwave properties in the same concentration in each composite. The analysis on dielectric properties of the composites concludes the significant influence of integrating the unsaturated polyester resin with pyrolysed carbon from palm shell residue to be used as microwave absorber.

ACKNOWLEDGEMENT

The authors wish to thank the Ministry of Science, Technology and Environment under the IRPA Research Programme for the research grants awarded (Vot No. 72107) as well as UTM for the supports in carrying out the research work.

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