DEVELOPMENT AND CHARACTERIZATION OF MICROWAVE ABSORBER USING RICE HUSK/CARBON NANOTUBE COMPOSITES

By

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LIST OF ABBREVIATIONS

AC	Alternative Current
L-1	Layer 1
L-2	Layer 2
CNT	Carbon Nanotubes
CST	Computer Simulation Technology
EM	Electromagnetic
EMC	Electromagnetic Compatibility
EME	Electromagnetic Environment
EMW	Electromagnetic Waves
EMI	Electromagnetic Interference
FF	Far Field
FL	Front Layer
FSS	Frequency Selective Surfaces
FDTD	Finite Difference Time Domain
GHz	Giga Hertz
IL	Insertion Loss
MAMs	Microwave Absorbing Materials
MEKP	Methyl Ethyl Ketone Peroxide
MIL-STD	Military Standard
MUT	Material Under Test
NF	Near Field
NRL	Naval Research Laboratory
PEC	Perfect Electric Conductor
PNA	Performance Network Analyzer

PE	Polyester
RAM	Radar Absorbing Material
RH	Rice Husks
RHA	Rice Husk Ash
SE	Shielding Effectiveness
SOLT	Short Open Load Thru
TE	Transverse Electric
TM	Transverse Magnetic
TEM	Transverse Electromagnetic
TRL	Thru Reflect Load

LIST OF SYMBOLS

μ_r	Relative Permeability
μ'_r	Real Part Complex Permeability
μ''_r	Imaginary Part Complex Permeability
ε_r	Relative Permittivity
ε'_r	Real Part Complex Permittivity
ε''_r	Imaginary Part Complex Permittivity
γ	Wave Propagation Constant
α	Attenuation Constant
β	Phase Constant
t	Thickness
t_m	Matching Thickness
Z_{in}	Input Impedance
f	Frequency
f_m	Matching Frequency
dB	Decibel
Γ	Reflection Coefficient
T	Transmission Coefficient
λ	Wavelength
λ_m	Matching Wavelength
l	Length of Single Layer Absorber
θ	Angle of incidence
Z_L	Load Impedance
n	Characteristic Impedance
n_0	Characteristic Impedance of Air
n_m	Characteristic Impedance of dielectric medium

ω	Angular Frequency
σ	Conductivity
S_{11}	Reflection S-parameter
S_{21}	Transmission S-parameter

PEMBANGUNAN DAN PENCIRIAN PENYERAP GELOMBANG MIKRO MENGGUNAKAN SEKAM PADI / KOMPOSIT TIUB NANO KARBON

ABSTRAK

Penyerap gelombang mikro yang terdiri daripada komposit tiub nano karbon telah menarik perhatian besar dalam dunia industri dan akademik kerana peningkatan keupayaan mereka dalam penyerapan gelombang mikro dan sifat bahan tersebut.Oleh yang demikian, sisa hasil pertanian seperti sekam padi (RH) dan abu sekam padi (RHA) dengan tiub nano karbon (CNT) telah digunakan untuk meningkatkan sifat-sifat penyerap gelombang mikro seperti sifat-sifat dielektrik, penyerapan gelombang mikro dan keberkesanan perlindungan gelombang elektromagnet.Di dalam tesis ini, penyerapan gangguan elektromagnetik (EMI) dan keberkesanan perlindungan penyerap gelombang mikro terdiri daripada RH, RHA, RH / CNTs, dan RHA / CNTs dibentangkan. Objektif utama tesis ini adalah untuk mencirikan pelbagai CNT dicampur dengan komposit RH dan RHA dalam sifat-sifat gelombang mikro termasuk sifat-sifat dielektrik, penyerapan gelombang mikro dan keberkesanan perlindungan. Hal ini menunjukkan bahawa sifat-sifat elektrik dan kekonduksian elektrik komposit RH/CNT dan RHA/CNT meningkat dengan peningkatan kandungan CNT. Pada tahap tertentu dan spesifik, komposit RH/CNT dan RHA/CNT adalah calon dan bahan yang sangat baik untuk dijadikan sebagai bahan dalam penyerapan gelombang mikro.Penggunaan CNT di dalam komposit RH/CNT dan RHA/CNT sebagai penyerap dielektrik adalah inovatif dan boleh memberi sumbangan besar dalam usaha untuk meningkatkan prestasi kajian sebelumnya iaitu penyerap gelombang mikro berbentuk piramid menggunakan sekam padi. Di dalam kajian ini, langkah pertama ialah sampel telah difabrikasi dalam bentuk komposit dengan mencampurkan RH, RHA, dan CNT dengan nisbah berat yang berbeza dengan ejen pengikat iaitu poliester (PE) dan sampel telah disediakan di dalam suhu bilik dengan menggunakan acuan dan proses fabrikasi mengikut piawaian yang ditetapkan. Kemudian, sifat-sifat dielektrik sampel telah diukur menggunakan Agilent pengukur dan sensor dielektrik jalur lebar dan kaedah pandu gelombang segi empat tepat dalam julat frekuensi 2-18 GHz frekuensi dan 8.2-18 GHz frekuensi , masing-masing. Sifat-sifat dielektrik yang diukur, digunakan untuk menentukan ciri–ciri galangan, gelombang pelemahan hidorologi malar, fasa malar, dan kedalaman penembusan gelombang kejadian itu di dalam komposit. Kajian ke atas sifat-sifat dielektrik komposit digunakan untuk membentuk penyerap berbentuk lapisan tunggal, pelbagai lapisan, sepenuhnya dipenuhi dengan bahan membentuk pepejal, dan penyerap piramid gelombang mikro yang berongga. Penyerap gelombang mikro telah dikaji secara eksperimen untuk mengkaji keberkesanannya dalam penyerapan gelombang

mikro (pantulan) dan keberkesanan penentangannya dalam menghalang gangguan elektromagnet (EMI). Bagi lapisan tunggal, di dalam julat operasi frekuensi yang spesifik iaitu julat frekuensi yang kecil, nilai pantulan penyerap didapati jauh di bawah -20 dB (penyerapan 99%) .Untuk penyerap pelbagai lapisan, prestasi pantulan adalah di bawah -10 dB dengan pelbagai jalur telah dicapai pada 2-18 GHz frekuensi. Pantulan bagi penyerap gelombang mikro RH berbentuk piramid telah bertambah baik daripada -20 dB kepada -40 dB pada 2-10 GHz frekuensi dengan menggantikan komposit 1 cm lapisan asas RH penyerap piramid yang mengandungi 70% berat RH dan 2% berat CNT (RH / CNT-2). Bagi penyerap gelombang mikro berbentuk piramid yang berongga, teknik menyaluti penyerap telah digunakan untuk meningkatkan prestasi pantulan penyerap piramid yang berongga dalam julat frekuensi 4-18 GHz. Keberkesanan perlindungan dan penentangan komposit yang terdiri daripada 70% berat RHA dan 20% berat CNT mencapai lebih daripada 25 dB pada 8.2-18 GHz frekuensi dalam sudut putaran penyerap yang berbeza.

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ABSTRACT

Microwave absorber composites with nanomaterial have tremendous attraction in both industrial and academic world due to their improvement of microwave absorption and material properties. Therefore, the rice husk (RH) or rice husk ash (RHA) with carbon nanotubes (CNT) composites have used to improve several microwave properties of microwave absorber such as dielectric properties, microwave absorption, and shielding effectiveness. In this thesis, the EMI absorbing and shielding of microwave absorbers composted of these RH, RHA, RH/CNTs, and RHA/CNTs composites are presented. The main objectives of this thesis were to characterize the various CNT mixed with RH and RHA composites in microwave properties including dielectric properties, microwave absorption, and shielding effectiveness. It was found that the electric properties and electrical conductivity of RH/CNT and RHA/CNT composites increases with the increase of CNT loading. Innovative use of CNT in RH/CNT and RHA/CNT composites as dielectric absorbers can make significant contributions in our effort to improve the performance of previous work of rice husk absorber. First step of this study, the samples were fabricated in composite form by mixing different weight ratio filler of the RH, RHA, and CNT, with the bonding agent polyester (PE), and the samples were prepared in room temperature by using standard mould and fabrication process. Then, the dielectric properties of the samples were measured using a broadband Agilent dielectric probe and rectangular waveguide methods over the frequency range of 2-18 GHz and 8.2-18 GHz, respectively. The measured dielectric properties were used to calculate the wave impedance, wave attenuation constant, phase constant, and depth of penetration of the incident wave in the composites. These composites then used, to fabricate single layer, multi-layer, fully filled solid, and hollow pyramidal microwave absorbers. The microwave absorbers were studied experimentally for their effectiveness in microwave absorption (reflectivity) and shielding effectiveness in suppressing the broadband electromagnetic interference (EMI). In case of single layer, the reflectivity values of the absorbers were found to less than -20 dB at specific operate frequency with narrowband performance. For multi-layer absorbers, the reflectivity performance is below -10 dB with multiple bands was achieved over 2-18 GHz. The reflectivity of RH based pyramidal absorber were improved from more than -20 dB to less than -40 dB at 2-10 GHz by replace the 1 cm RH base layer of pyramidal absorber to 70 wt% RH and 2 wt% CNT composite (RH/CNT-2). In case of hollow pyramidal absorbers, coating layer technique was used to improve the reflectivity performance of hollow pyramidal absorber over 4-18 GHz. The Shielding effectiveness of the 70 wt% RHA and 20 wt%

CNT composite achieved more than 25 dB over 8.2-18 GHz in different angle rotation of absorber.

CHAPTER 1

INTRODUCTION

1.1 Background

Microwaves were found wide and varying use throughout society and industry. This technology is so pervasive that many use it daily, though few may realize this. This form of microwave radiation is roughly defined as waves with a frequency between 300 MHz and 300GHz. However, the electromagnetic pollution increase promoted by the rapid development of electronic and telecommunication systems has expanded in the form of electromagnetic interference (EMI) (H. Li et al., 2009). As commercial, military, scientific electronic devices and communication instruments are more widely used, electromagnetic interference shielding of radio frequency radiation continues to be the most concern in this modern society. EMI shielding is needed to protect the workspace and environment from surrounding electronics, computers and telecommunication equipment radiations coming from as well as to protect sensitive circuits within a system. In order to control the problems created by EMI, the electromagnetic wave absorbing technology is an important topic to be considered. Microwave absorbing materials used in anechoic test facilities consider many forms, depending on the purpose of the facility and frequency of operation. The two most common are the dielectric absorbers used in the microwave frequency range and the ferrite absorbers used in the lower frequency range. Dielectric absorbers came during the development of anechoic chambers in the early of 1940s when indoor test facilities were first developed which is used as microwave absorber (L.H. Hemming, 2003). In both civil and military

applications, microwave absorbers have the ability to eliminate or minimize the electromagnetic reflection wave from the metal plate such as aircrafts, ships, tanks and the walls of anechoic chambers and electronic equipment. In general of the military area, the studies involve development of radar absorbing material (RAM) in the frequency range of 8 to 12 GHz (Folgueras, Nohara, Faez, & Rezende, 2007). The production of RAM is interest in development of new materials for providing several applications including the microwave reflection suppression. For this purpose, RAM is used to cover the surface of targets, which can consist of different types of equipment, land vehicles, and aircraft.

Microwave absorbing materials (MAMs) are usually developed from magnetic and dielectric materials in powder form. The powder form of magnetic and electric material need polymeric binders to bind those powder materials. Most of the polymeric matrices are transparent to microwaves, and absorption, due to the microwave measurement resulting with very low loss of dielectric and magnetic dipoles of the particulates in polymeric materials. The interest in dielectric properties of materials has historically been associated with the design of electrical equipment is made by dielectric materials which are used for microwave absorbers, insulating conductors and other components of electrical equipment. Measurement of the dielectric properties of bulk materials usually involving dielectric constant, dielectric loss factor, dielectric loss tangent. The dielectric properties of dielectric absorber are an important parameter, which determines the absorption properties of the dielectric material (Oyharçabal et al., 2013; Zhai, Zhang, & Ren, 2012). Therefore, efficient and broadband measurements for dielectric properties and magnetic properties of materials have great interest in material