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Review on Microwave Absorbing Material using Different Carbon Composites

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***Abstract*—In this paper we propose an optimal design about radar absorbing materials (RAM), using different composites materials, as well their absorption capability are analyzed and numerical design of wide frequency band microwave absorbing structure presented. It is shown that value of the relative permittivity of the substrate should high, as it is essential for absorption property. Motive of present this work is to optimize microwave properties, using different carbon compositions, these described in detail, and type of material considered the absorption capability taking into account both the reflection and the absorption property of RAM at frequency 2-20 GHz.**

***Keywords* – permittivity, permeability, EM – electromagnetic property, MWCNT - multiwall carbon nanotubes, carbon black.**

I. INTRODUCTION

There is an increasing demand for lightweight Radar Absorbing Material (RAM) in both commercial and military applications.Many promising applications in the stealth technology of aircraft, television image interference of high-rise buildings, near field absorber, loads , millimeter wave absorber, reflection reduction, radar cross section reduction, anechoic chamber.

This paper is focused on the field of microwave absorbing materials (RAM). We want to increase the absorption and decrease the reflection as much as possible. Bandwidth of the material should also be high for good absorption capability. Many conductive and magnetic materials have been trailed for absorption including carbon, metals and conducting polymers. And also Composite materials too plays important role in research. As carbon is using now days in many applications [1-2]. Radar absorbers can be classified as impedance matching or resonant absorbers. Radar absorbing materials are made from resistive or magnetic materials. Materials behind these devices includes, complex permittivity, permeability and microwave absorption properties of the composites are discuss in the frequency range of 2–20 GHz. Here, Core material Carbon is usedwith different compositions of materials.

II. MICROWAVE ABSORBERS

Microwave absorbers presented with two important features of their electromagnetic properties. The first was magnetic losses and second is feature dielectric losses. The classification of absorbers can be done by standard measurement methods, i.e. direct measurement of the reflection in free space or indirect measurements of their electromagnetic parameters.

Requirements for the absorber are as follows:

- Material should minimize the front-face reflection and impedance matching at the air to absorber interface.
- Material should increase the absorption of electromagnetic waves through high values of dielectric and magnetic losses.
- Material is expected to be applied in a wide frequency range.
- Material does not require the use of an external magnetic field.
- Material should be light weighted.

III. TYPES OF ABSORBING MATERIALS

Microwave Absorbers can be classified into impedance matching absorber and resonant absorbers, there features are discussbelow, First one is Graded Interfaces or impedance matching, shows graded interface to match impedance or we can say a gradual transition in material properties for impedance matching, includes pyramidal, tapered and matched layer absorber. Second one is Resonant materials also called tuned or quarter wavelength absorbers and includes Dallenbach layers, Salisbury Screen and Jaumann layers[3].

1) IMPEDANCE MATCHING

Propagating wave that works on an interface will experience some reflection that is proportional to the magnitude of the impedance step between incident and transmitting media. For complete attenuation of the incident wave one or more wavelengths of material are required, which make them bulky.

a) Pyramidal Absorbers

Pyramidal or cone absorber was extending perpendicular to the surface in a regularly spaced pattern. These absorbers were produce so that the interface presents a gradual transition in impedance from air to that of the absorber. The height and periodicity of the pyramids tend to be on the order of one wavelength. Pyramidal provide high attenuation over wide frequency and angle ranges. These absorbers provide the best performance. Although Pyramidal absorbers made by thick materials. The disadvantage of pyramidal absorbers was that their thickness and tendency of fragile. They were usually used for anechoic chambers. Morerobust flat “pyramidal” absorbers fabricated using multilayers with a pyramidal type structure being described by resistive sheets.Shown in*Fig.1*

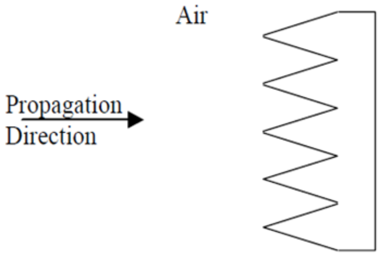

Fig.1 pyramid absorber [3]

b) Tapered Loading Absorbers

Structure of taperedabsorber is kind of slab and composed of a low loss material mixed with a lossy material. The structure made up as follows, lossy component was homogeneously spared parallel to the surface, with a gradient perpendicular to the surface and increasing into the material. Composition of material includes open celled foam, dipped or sprayed with lossy material from one side, or allowed to drain and dry. It was difficult to reproduce fabricate a gradient in this manner. A second type is composition of homogeneous layers with increasing loading in the direction of propagation i.e. The gradient is created as a step function as shownin *Fig.2* The advantage of these materials is that they are thinner than the pyramidal absorbers. The disadvantage is that they have poorer performance and it is best to vary the impedance gradient over one or more wave lengths.

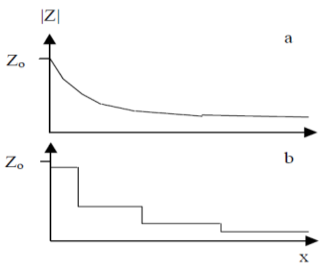

Fig.2 Tapered absorber (a) smooth (b) stepped [3].

c) Matching Layer Absorbers

Aim of the matching layer absorber reduces the thickness required for the gradual transition materials. This absorber places a transition absorbing layer between the incident and absorbing media. The transition layer has thickness and impedance values that chosen between the two impedances to be matched i.e. the absorber and incident media. The idea there have the combined impedance from the first and second layers to equal the impedance of the incident medium, as shown in*Fig.3.*This matching occurs when the thickness of the matching layer is one quarter of a wavelength of the radiation in the layer and the impedance matching occurs only at the frequency that equals the optical thickness. This makes the matching layer materials narrow band absorbers. These absorbers are made using an intermediate impedance and quarter wavelength thickness for absorption at microwave frequencies.

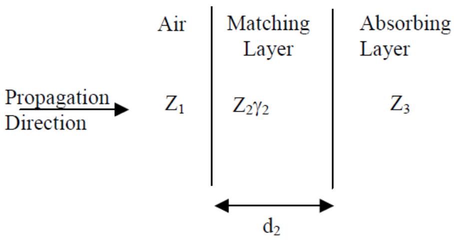

Fig.3 Matching layer absorber [3]

This arrangement results in reflection and transmission at the first interface. In all of the aforementioned absorption techniques, the widening of the absorption band is achieved by creating an additional resonance in the vicinity of the primary resonance[4]. If the magnitude of the two reflected waves is equal then the total reflected intensity is zero [3]. Our aim is to increase the permittivity that is essential for operation of absorber[4].

a) Salisbury absorber

Salisbury Screen called Salisbury absorber deals with antireflective concept of RAM (radar absorbent material)[3]. In Salisbury absorber a resistive sheet is placed at λ/4 is placed on distance over ground plane to generate losses to incident field.as shown in Fig.4the thickness of the resistive sheet for optimum absorption has an inverse relationship to the sheet conductivity [4].

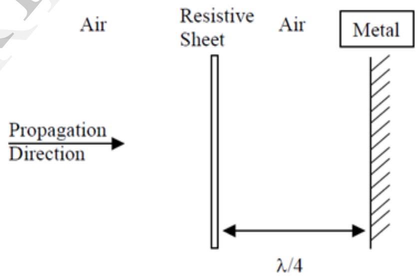

Fig.4 Salisbury absorber [4]

b) Jaumann absorbers

In Jaumann absorbers a resistive sheets are stacked over each other at an approximate distance of a quarter wavelengths that measured at the center frequency of the absorption band, distance generating a wider absorption band compared to the Salisbury absorber [4]. See Fig.5

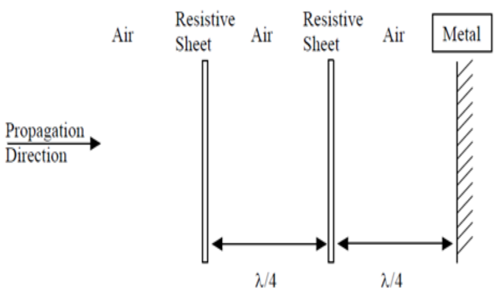

Fig.5 Jaumann Absorber [3]

c) Dallenbach layer.

In Dallenbach absorber the structure is similar to the previous ones, with the exception that no resistive sheets are used, but the incident power is dissipated in lossy homogenous dielectric materials layered on top of each other over a ground plane. Reflectivity Dallenbach layer has been simulated using CAD tool called touch stone [3]. Dallenbach layers have been patented based on ferrite materials. The use of two or more layers with different absorption bands will increase the absorption bandwidth. The bandwidth of standard ferrite absorbers have been improved through a two layer absorber design, with a ferrite layer at the air/absorber interface and a layer containing ferrite and short metal fibers at the absorber/metal interface. Shown in Fig.6the ferrite layer acts as an impedance matching layer as well as absorber.

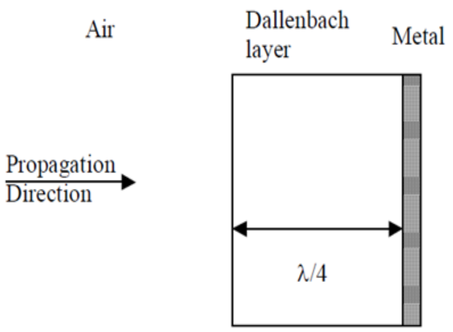

Fig.6 Dallenbach layer [4]

IV. STUDY OF MICROWAVE ABSORBING PROPERTIES OF CARBON NANOTUBES-EPOXY COMPOSITES

Material built by Compositeof carbon nanostructured materials wasconsidered, mainly because of their important electromagnetic characteristics, as high electrical conductivity and excellent microwave absorption [5]. This section is focused on carbon Nano tubes (CNTs) and Multi-walled carbon nanotubes (MWCNTs) these are very flexible to design & control for microwave absorption and composites made-to-order through change in loading fractions [6]. Also carbon Nano fibers & tubes used to increase permittivity of resin to enhance absorption in 8-20 GHz frequency. Absorption ability of material to dissipate as in form of heat [7]. In experimental study MWCNT with outer diameter less than 8nm, that was pure about 95%, Ash contains 1.5 WT%, length taken from 10 to 50 μm. MWCNT – epoxy made by chemical mixture method. Inner and outer diameter is 1.5mm & 3.5mm Carefully cut them to thickness of 2mm. Maximum loading provided as 10 wt.%. Result of SEM morphology with epoxy composite of 1 – 7 wt. %. MWCNTwould form agglomerates (balls) ofirregular size & shape in epoxy matrix as shown in

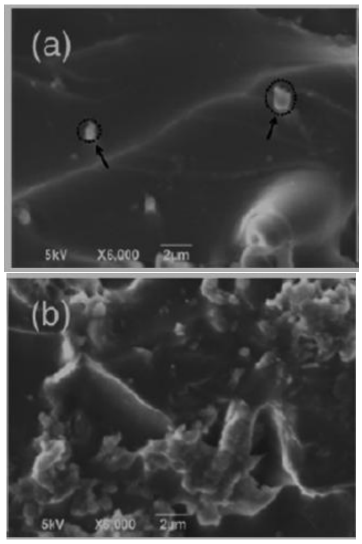

Fig.7 SEM images of the MWCNTs - epoxy composite samples with (a) 1.0 wt. % and (b) 7.0 wt. %[6]

Measurement of permittivity

Absorption is related to permittivity (ε) and permeability (μ)as loading effects increases and permittivity also increases. Real part shows how much energy can be stored from external EM field for real partpermittivity (ε) [6]
As shown in *Fig.8*

Table 1[6]

Loading factor	Permittivity (ε)	Frequency
1-3 wt.%	~3.0 - ~4.0	2-20 GHz
8-10 wt.%	~7.0 - ~ 8.0	2-20 GHz

Real part shows how much energy can be stored from external EM field.

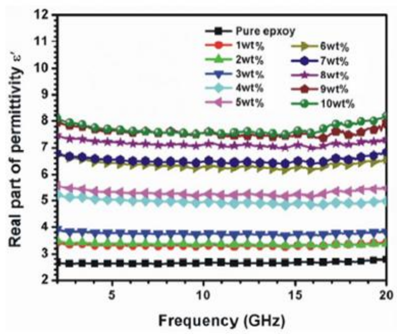

Fig.8 Graph of permittivity $v_{s.}$ frequency [6]

And Imaginarypart ε″ part shows that how lossy material is toward external EM field. So absorption increases by increase in loading factor as in Table 2 [6]

Table 2 [6]

Loading factor	Permittivity (ε″)	Frequency
3 wt.%	0.1-0.3	Not frequency dependent 2-20 GHz
Above 4 wt.%	---------	Shows Frequency dependent
10 wt.%	0.8	2GHz
10 wt.%	1.0	10GHz
10 wt.%	1.9	19GHz

Whereas permeability (μ) shows the magnetism in MWCNT and epoxy resin. Real part of permeability shows decrease range imaginary part show absorption up to ~ 0.8, mainly attribute to the dielectric losses. As shown in Fig.9

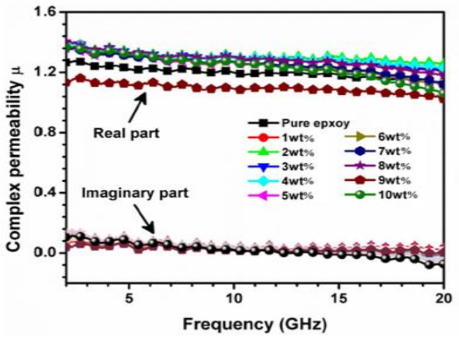

Fig.9 Graph of permeability v_s frequency [6]

In nutshell, fabricated carbon nanotube with MWCNT loading from 1-10 wt. % measured samples at 2-20 GHz. Thus absorption depends on loading factors achieved absorption ratio up to 20% - 26% near about at 18 -20 GHz range with 8 – 10 wt.% MWCNT loadings factors.

V. MICROWAVE ABSORBING PROPERTIES OF EPOXYMWCNT COMPOSITES

Epoxy resin filled with MWCNT were analyzed in this case permittivity is measured under 3- 15 GHz range with commercial a sensor. The microwave absorbing properties of a one-layer absorber backed by a metallic plate were then investigated by means of numerical simulations.Multi Walled Carbon Nanotubes used as fillers have been analyzed. These done with composites CNT composites used as epoxy resin with property of thermostat – T 19-36/700. MWCNT used – Nanothinx of diameter 6-10nm, length was greater than 10μm, purity greater than 90%. MWCNT Sample prepared with concentration of – 0.5,1,3,5 wt. % above 7 wt. % would difficult to realize homogeneity. Sample prepared with following procedure as;

- MWCNT & epoxy were mixed.
- Mixture was spread using ultra turrax mixer for 10 min. to make solution.
- Curing agent added ratio 6:10 w.r.t. epoxy & stirred for 10 min.
- Now sonicated for 30min.with unbind bundles.
- Mixture then poured to cylindrical molds with diameter 20mm then degassed in vacuumed for 20 min.
- Dried in oven for 3 hrs.at 70^0 [8].

Complex permittivity of epoxy resin filled with MWCNT measured at 3-18GHz using commercial sensor sample &network analyzer. Permittivity shown inFig.*10*[8]

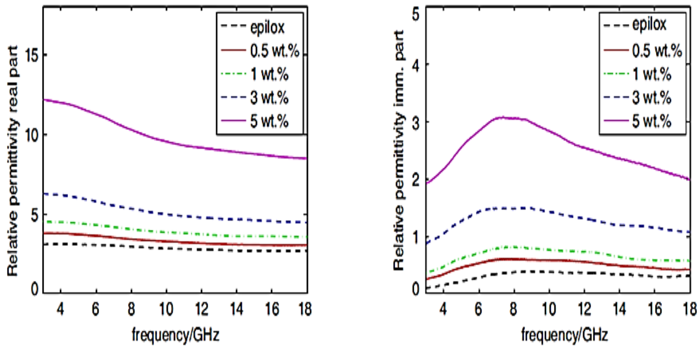

Fig.10permittivity of the pure Epoxy resin and with different MWCNT concentrations.

Analyzed numericallythat absorbing property of polymer considers on layer given thickness (TM) & perpendicular (TE).

Expressed in Equation 1&Equation 2.

$$Z^{T\,E}_{1,2} = \frac{\omega\mu}{k_{z1,z2}}$$

Equation 1

$$Z^{T\,E}_{1,2} = \frac{\omega\mu}{k_{z1,z2}}$$

Equation 2

Modeling of transmission line with matrix a is as Equation 3

$$a1 = A_{11}b_2 + A_{12}a_2$$
$$b_1 = A_{21}b_2 + A_{22}a_2$$

Equation 3

where a1,a2,b1,b2 are incident (ai) and reflected (bi) power waves at port 1 and 2, the reflection coefficient at the input port can be written as and shown in Fig.12

$$\Gamma_i = \frac{A_{21} - A_{22}}{A_{11} - A_{21}}$$

Equation 4

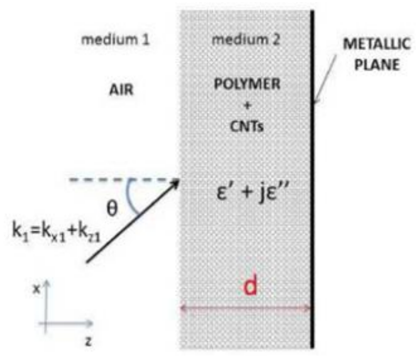

Fig.11 single layer absorber backed by a metallic plate [9]

Reflection is clear from Fig.12

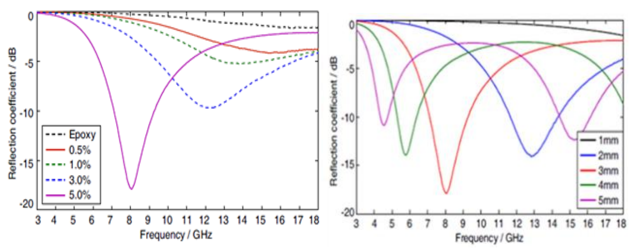

Fig.12 (a) Shows Reflection at thickness 3nm at normal incidence, (b) reflection coefficient, at normal incidence, MWCNT 5 wt.% for different thicknesses

At end result shows that values of permittivity increases as the filler concentration incr`eases. Due to effect reflection minimizes and observed maximum absorption.

VI. MICROWAVE ABSORBING PROPERTIESOF CNF/EPOXY COMPOSITES

As we know EM waves are complex that required impedance matching, so Carbon Nano fibers (CNF) are selected as lossy media. CNF produces high electric conductivity. This work shows different dielectric properties and absorbing performance. Method explained as; different CNF contents are prepared in a sample.CNF dispersion within solvent further taking elimination via evaporation or filtration. Two methods are entails dispersion of CNFs as [7]

First method

- Mixture is made by Dispersion of CNT_sin
- Buthylglico (BGE), 1ml solvent to 7mg fiber &
- Sonicated for 1hr.
- Add epoxy resin (Araldite Ly554).
- Stirred under room temp. Until l BGE evaporates.
- Finally, added hardener (HX956).
- Stirred until solvent could not evaporate.

second method

- Dispersed in BGE under sonication for 1 hr.
- Solvent removed via filter.
- Add resin & hardener.

It is clear from, increase inpermittivity as 4% in real part(ε′) from 8 - 20 GHz freq. also tested that sharp increase in imaginary part at 4% in same frequency range therefore conductivity increased these had correlated parameters expressed as in equation;

$$\sigma = 2\pi f \varepsilon_o \varepsilon''$$

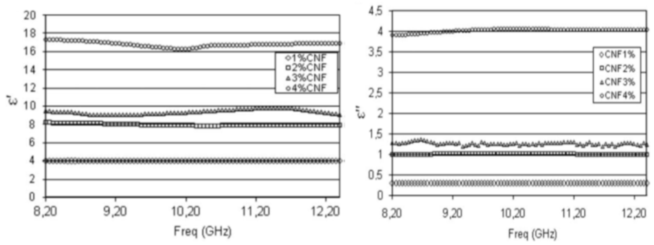

Fig.13 measurement of permittivity

Increase in conductivity leads to increase in permittivity hence TYPE 2 forms number of aggregates. It shows low dielectric constant therefore shows poor dispersion losses are expressed as follows in Fig.14

$$\varepsilon'' = \varepsilon_{relax} + \frac{\sigma}{\varepsilon_\circ \omega}$$

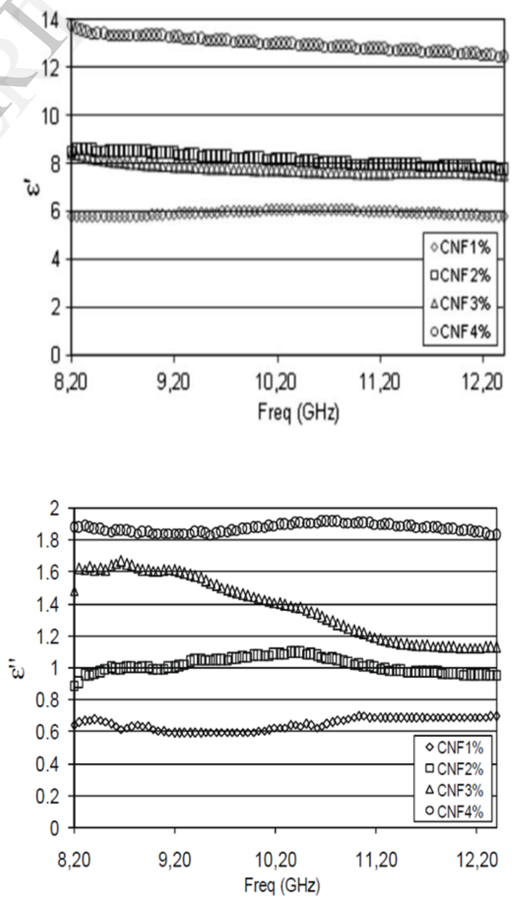

Fig.14 measurement of permeability

EM property of TYPE 2 shows at 4% permittivity reached up to 12-14 for real part and 1.8-2 in imaginary part at 4% frequency range remain same for both.

Table 3 [7]

Sample	Thickness (mm)	Freq. at peak (GH_Z)	Max. abs.at peak(db.)
Type 1-1%	1	20	-0.2
	2	19.8	-2.4
	3	14	-2.3
Type 1-2%	1	20	-1.3
	2	13.8	-5.2
	3	9.4	-5.2
Type 1-3%	1	20	-2
	2	12.6	-5.7
	3	8.4	-5.8
Type 1-4%	1	18.6	-18.3
	2,3	9.2,18.2	-18.9,-8.9

Balls are made in type 2 because of reflection. If conducive filler was small absorption will limited if choose too much large conductivity results in reflection so had to choose intermediate conductivity for system , results decrease in absorption. Thickness of sample was also an important part as expressed

$$\Gamma = \frac{Z_{in} - Z_0}{Z_{in} + Z_0}$$

where Z_{in} is

$$Z_{in} = Z_c \frac{Z_L + Z_C \tanh(\gamma d)}{Z_C + Z_L \tanh(\gamma d)}$$

So we can measure maximum peak absorption and frequency at thickness up to 3mm only. Finallyabsorption and frequency are shown in tables with Table 3 [7] and **Error! Reference source not found.**respectively.

Table 4

Sample	Thickness (mm)	Freq.at peak (GH_Z)	Max. abs. at peak(db)
Type 2-1%	1	19.9	-0.4
	2	17.9	-4.2
	3	11.8	-4.2
Type 2-2%	1	20	-1.18
	2	13.7	-5.8
	3	9.4	-5.3
Type 2-3%	1	20	-1.7
	2	13.8	-7.1
	3	9.3	-7.1
Type 2-4%	1	20	-6.6
	2	10.7	-7.6
	3	20	-10.8

VII. MICROWAVE ABSORPTION PROPERTIES OF CARBON BLACK/SILICON CARBIDE

Absorption medium was prepared using Nano size carbon black mixed with silicon carbide. Because carbon black has light weight property that's why used as EM absorption material.

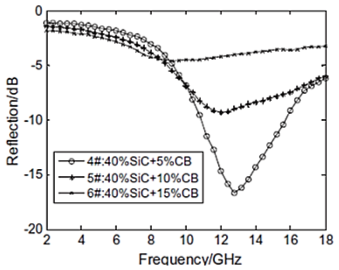

Fig.15 Reflection loss of SiC/EP composite due to effect of CB fraction

To fabricate 2mm thick composite carbon black 5 wt. % is mixed with silicon carbide 50wt%.this provides maximum reflection loss -41db at 9 GHz and -10 db. As in *Fig.15* Bandwidth at 6 GHz Finally, single layer with 2mm thickness mixed with carbon black and silicon carbide absorber. Provide good absorption in 2-18GHz range [9].

VIII. MICROWAVE ABSORPTION USING CNT_S/S_IO_2COMPOSITES

Another composition used by carbon nanotubes/ silicon. Absorbing enhanced by adding five kind of powder with different content of CNT to form multilayer CNT/S_io_2. Inresults of 5 wt. % CNT/Sio_2 with is 49.8%. The multilayered sample is 74.83% which is 1.5 times high than single layer. Because of good conductivity of CNTs, conductivity also increased layer by layer. EM wave go deeper in multilayer sample because reflection goes higher from topside to bottom side & top side reflection is lowest. With this composition the reflection reduces and absorption increased 1.5 times than single layer structure [10].shown in *Fig.16*

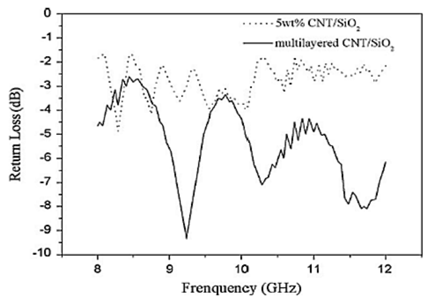

Fig.16Return loss of material with 5 wt. % CNT/Sio_2

IX. MICROWAVE ABSORPTION PROPERTIES OF CARBONYL IRON/CARBON BLACK DOUBLE-LAYER COATINGS

Absorption can increase by another composition that used Epoxy resin based double layer coating with thickness 1.2mm, absorbent used were carbonyl iron and carbon black using 2-18GHz range.By this reflection factor reduces & absorption bandwidth increases. See Fig.17Carbonyl iron powder made by conventional thermal decomposition process of ironpent carbonyl. Carbonyl iron, carbon black, siliconwas mixed in epoxy resin to form a composite. Weight of Sio_2 was at 2:5:1 reflection loss reaches to -17.3 db. & absorption is 5.7 GHz.

Here, Sio_2worked as matching layer. Carbonyl iron concentration improves absorption but up to threshold point.Reason behind this was that beyond that point there decrease in bandwidth occurs due to unmatched impedance. So Sio_2 improve matching impedance [11].

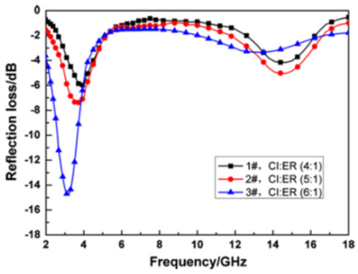

Fig.17 Reflection losses

X. MICROWAVE ABSORPTION USING MODIFIED CARBONYL IRON POWER

Absorbing agent was prepared by depositing copper particles on carbonyl iron power (CIP). Process method used an ultrasonic electro less copper plating method. Value of permittivity and permeability increases after this process. Non-woven fabric used as substrate which had low density and this beneficial for RAM.

Electro less copper plating reaction process; as per

Equation 5 below:

$$C_USO_4 + 2HCHO + 4N_aOH \rightarrow C_U + N_aSO_4 + 2HCOON_a + H_2 \uparrow + 2H_2O \qquad (1)$$

$$2C_USO_4 + HCHO + 5N_aOH \rightarrow CU_2O + 2N_aSO_4 + HCOON_a + 3H_2O \qquad (2)$$

$$CU_2O + 2HCHO + 2N_aOH \rightarrow 2C_U + 2HCOON_a + H_2 \uparrow + H_2O \qquad (3)$$

$$2HCHO + N_aOH \rightarrow CH_3OH + HCOON_a \qquad (4)$$

Equation 5

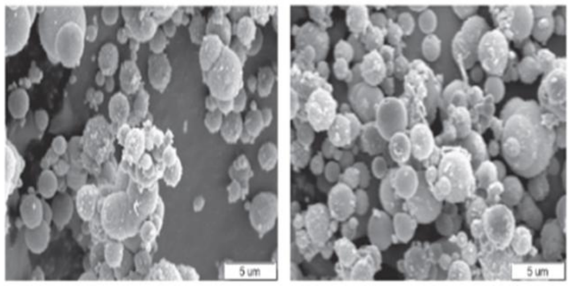

Fig.18(a) modified CIP by non-woven electro less plating (b) modified CIP by ultrasonic electro less plating

Minimum reflection loss-8.43db. Atthickness of 2mm,in range of 8-12 GHz. Non-woven fabric absorption material also had reflection loss-26db. With thickness of 2.08mm at 9.53 GHz. Absorption increase by ultrasonic method with electro less copper plating together on CIP. Fabric was used of light weight FCAM(fiber coated absorbing material) had low density about 0.2 kg/m [12].

Another morphology control and microwave absorption property was discussed as varying morphology of Z_NO was coated on carbon fiber. Materialpermittivity and permeability of composite with two different morphology were measured at 1-18GH_Z.Thiscomposite shows strong microwave absorption properties (RL < -10 dB) in a wide frequency of 3.4–18 GHz and the strongest absorption of RL = -46.6 dB is obtained at 17.8 GHz with a thickness of only 1.21mm.This composition gives better microwave absorbent with light weight, Small thickness and wide bandwidth [13].

XI. CONCLUSION

In this paper different type of microwave absorber was analyzed with different type of materials that used to increase the absorbance and to reduce reflectivity. The combination of epoxy resin with multiwall carbon nanotubes results in a new functional material with enhanced electromagnetic properties. Also increases the permittivity as increase MWCNT concentration results absorption increases. The analysis of experimental data shows that Carbon material used for many branches of modern technology. As per the papers use of Epoxy/MWCNTs absorption increase as loading factor increases as 8-10 wt. %. Loading factor at 18-20 GHZ.20-26 % absorption. Another increases permittivity at 3-15 GHZ, with sensors. As filler concentration increase, so absorption increase. CNF produces high electric conductivity hence increase in absorption. And using carbon black/silicon provide maxi. Reflection loss at 9 GHZ with CNTS/SIO2 absorption increase 1.5 time more than single layer structure.Its determined that carbon black double layer coating increase absorption bandwidth and reduce reflection with 2:5:1weight of SIO2 Next steps will be oriented to increase performance of our Nano composite using other types of MWCNTs and to analyses and tune an n-layer structure.

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