Microwave Absorption Studies of γ-ferrite & Ni-Zn ferrite / Epoxy based Nano Composite

K. C. Tripathi[1, 3], S. M. Abbas[1], R. B. Sharma[2, 3], P. S. Alegaonkar[3], Manish Verma[1]

[1,4] Defense Materials and Stores Research and Development Establishment, Kanpur-208 013, India

[2] 240, DRDO Bhawan, Rajaji Marg, New Delhi-110 011, India

[3] Defence Institute of Advance Technology, Pune-411 025, India

Abstract- *Epoxy based NiZn Ferrite have been studied recently for stealth & Electromagnetic Interference (EMI) applications. We have prepared toroidal shaped sample having composition wt. 40% γ-nano ferrite & wt. 20% Ni-Zn ferrite/epoxy based nano composites for microwave absorption and electromagnetic interference shielding. The permittivity and permeability measurements have been carried out using vector network analyser (Model PNA E8364B, Software module 85071E) attached with coaxial measurement set up in the range 2-15 GHz. In the present study we report the systematic algorithm & variation of complex electromagnetic parameters (ε, μ), reflection loss (RL) with the applied frequency. Further, the microwave reflection loss measurements of the nano composite have been analyzed in the S, C, X band (2 to 10 GHz) frequency for various sample thicknesses using algorithm for reflection loss for single layer PEC backed condition. The morphology and thermal behavior of the nano-composite samples have also been investigated through scanning electron microscope (SEM) and thermo gravimetric analysis (TGA) techniques.*

Keywords- Permittivity, Permeability, Perfectly electric conductor (PEC), Reflection loss

I. INTRODUCTION

Magnetic Nano-composites have been recently studied due to their excellent electromagnetic properties, light weight and thermal stability. In principle, high permeability (magnetic loss properties) and high permittivity (dielectric loss properties) enables Ni-Zn ferrite based RAM [1, 2] for phenomenally good absorption at very high frequencies (GHz) and in lesser thicknesses. Such microwave absorbing ferrites [3] can be potential candidate to mitigate the EMI/EMC issues and provide passive stealth [4] against the operational enemy RADARs in military aircraft and unmanned aerial vehicles at phenomenal wider range of operations. Ni-Zn ferrite based nano-composites have been synthesized in different geometries such pyramidal, cutting cone, rectangular, cylindrical, bird eye shaped etc [5-8]. Recently several studies have been conducted on the metal backed single layer nano-composite absorber [9-11]. This paper presents the preparation of γ-ferrite & Ni-Zn nano-ferrite/Epoxy based Nano Composite samples and the microwave absorption properties for metal backed single layer condition of varying thickness have been simulated and their performance evaluation for EM and microwave absorption properties have been discussed for 2-15 GHz frequency range.

II. MATERIALS & METHODS

In order to measure the Electromagnetic parameters & Microwave absorption properties for a single layer metal backed material is systematically illustrated by a sequential algorithm in figure A.1.

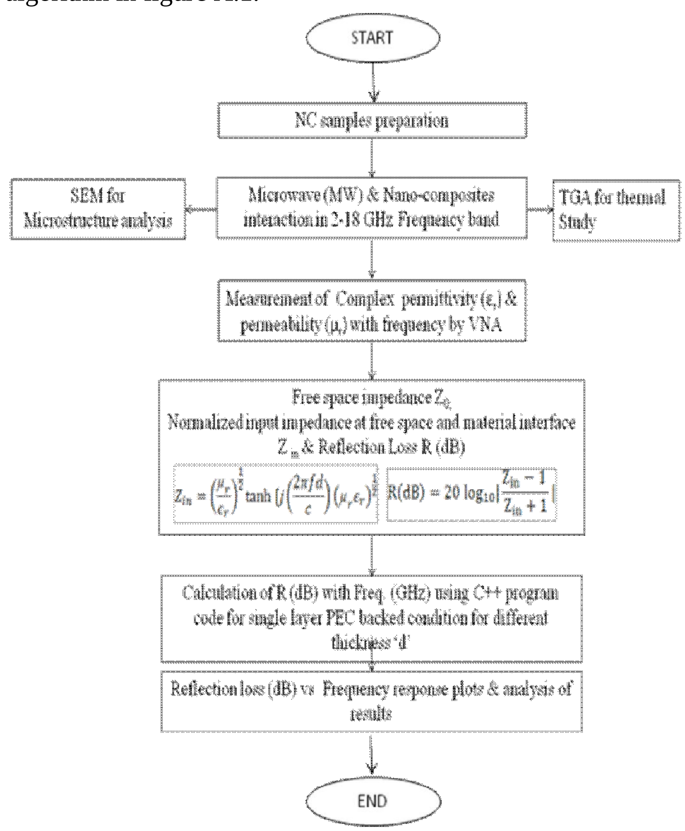

Figure A.1

The fabrication of the nano composite sample has been carried out using wt. 40% γ-nano ferrite & wt. 20% Ni-Zn nano ferrite as fillers in epoxy matrix. The Ni-Zn nano-ferrite and γ-nano ferrite were thoroughly mixed in two component epoxy matrix as illustrated in table A.1. The mixture was homogenized in mortar and pestle and then put in the mould (fig. A.2) followed by curing it under heat and pressure in a hydraulic press. The samples are prepared in toroidal shaped with an outer diameter of 7.0 mm, an inner diameter of 3.0 mm (fig. A.2) to fit in co-axial waveguide sample holder.

Materials Used:
Ni-Zn Nano Ferrite
γ-Nano ferrite
Epoxy

Table A.1

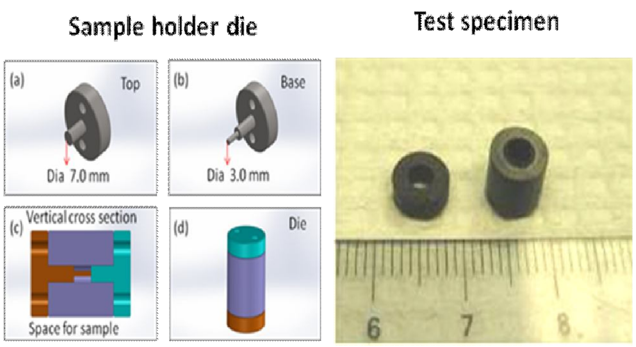

Figure A.2

Microwave measurements

Microwave absorbing properties were studied using coaxial line method. Electromagnetic parameters (complex Permittivity and Complex permeability) of composite were investigated using AGILENT vector network analyser Model PNA E8364B (fig. A.3) for the frequency range of 2 MHz to 15 GHz.

Figure A.3

Further, the reflection loss (R_L) with different thicknesses (t) have been derived from equations (1) and (2) given below:

$$RL(dB) = 20 \log_{10} \left| \frac{Z_{in}-1}{Z_{in}+1} \right| \quad \ldots\ldots(1)$$

$$Z_{in} = \left(\frac{\mu_r}{\epsilon_r}\right)^{\frac{1}{2}} \tanh \left[j \left(\frac{2\pi f d}{c}\right) \left(\mu_r \epsilon_r\right)^{\frac{1}{2}} \right] \ldots\ldots(2)$$

where Z_{in} is the normalized input impedance at free space and material interface, $\varepsilon_r = \varepsilon' - j\varepsilon''$ and $\mu_r = \mu' - j\mu''$ is the complex permittivity and permeability of the material. Real part is a measure of the extent to which the material will be polarized or magnetized by the application of electric or magnetic field respectively while imaginary part is a measure of the energy loss incurred in re-arranging the alignment of the electric or magnetic dipoles as according to applied ac fields, d is the thickness of the absorber, and c and f are the velocity of light and the frequency of microwave in free space, respectively.

III. RESULTS & DISCUSSION

3.1. Morphological Properties

Morphological properties of nano composite have been analyzed by scanning electron microscopy (SEM) (Carl Zeiss EVO-50). The SEM micro graph in figure A.4 depicts that the Ni Zn ferrite spherical nano-particles and γ-Ferrite nano particles are dispersed in epoxy matrix.

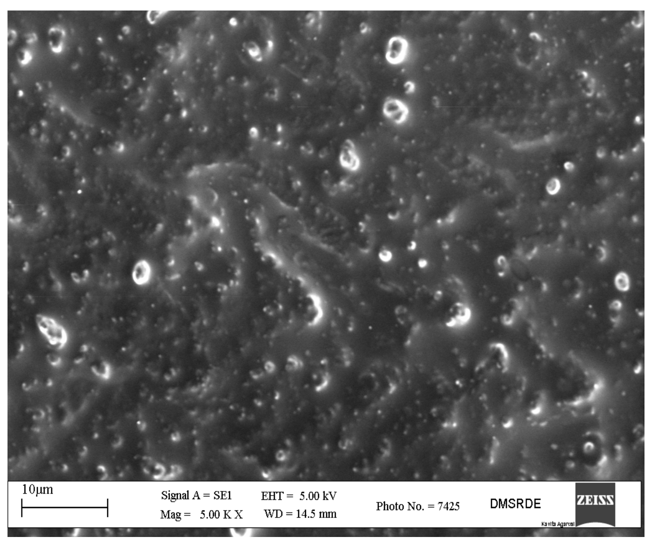

Figure A.4 SEM micrograph of Nano-composite

3.2 Thermal Properties

Thermo gravimetric analysis (TGA) has been carried out to study the thermal stability of the prepared nano-composite sample. Figure A.5 shows the TGA plot of prepared nano-composite which exhibits weight loss in several steps.

But the prepared nano-composite is found to have a thermal stability at least up to 190 0C.

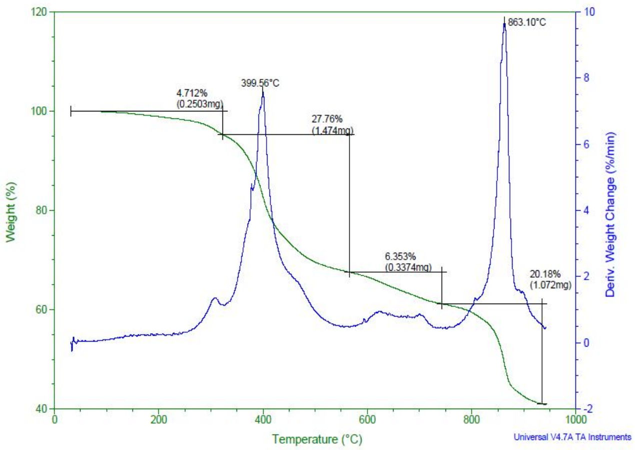

Figure A.5 TGA of Nano-Composite

3.3 Electromagnetic Parameters

The Permittivity and permeability are the two important electromagnetic design parameters for the stealth material and EMI shielding. Usually complex permittivity and complex permeability are measured with the Vector network analyzer.

3.3.1 Permittivity Spectra

The dissipative nature of the complex permittivity can be studied by taking the real and imaginary part separately. The real part of complex permittivity is called dielectric constant and the imaginary part is called the dielectric loss. In transient EM field, the nano-Ferrite composite sample exhibits the relation given by the equation (3):

$$\varepsilon = \varepsilon' - j\varepsilon'' \qquad (3)$$

ε' = Real part of ε i.e. Di-electric constant, ε"= Imaginary part of ε i.e. dielectric loss component and this is related to dielectric tangent loss (tan δ_e) by the relation equation (4).

$$\varepsilon = \varepsilon' (1- j \tan \delta_e) \qquad (4)$$

From fig A.6 it is evident that di-electric constant (real permittivity) varies with the frequency. The di-electric constant is found to vary from maximum value of 5.06 at frequency 9.04 GHz and a minimum value of 3.79 at a frequency of 12.88 GHz. The di-elcctric loss (imaginary permittivity) is also found to vary slightly with frequency and is measure of losses in nano-composite. The maximum di-electric loss is found to be 0.53 at a frequency of 9.04 GHz.

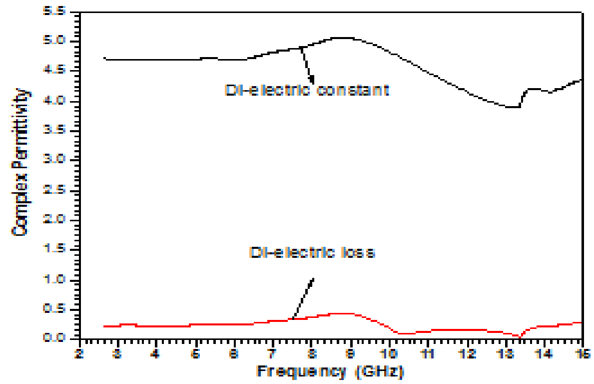

Figure A.6

3.3. Permeability Spectra

In transient EM field the nano-Ferrite composite exhibits the relation given by the equation (5):

$$\mu = \mu' - j\,\mu'' \qquad (5)$$

μ' = Real part of ε i.e. permeability constant
μ"= Imaginary part of μ

The dissipative nature of the complex permeability can be studied by taking the real and imaginary part separately.

The real part of complex permeability is called permeability and the imaginary part is called the magnetic loss. The permeability is found to vary with frequency and the magnetic loss is the measure of losses in composite The Complex permeability constant is found to vary with the magnetic tangent loss given by the relation (6)

$$\mu = \mu' (1- j \tan \delta_m) \qquad (6)$$

From fig A.7, the real permeability decreases from value 1.28 at frequency of 2.64 GHz to a minimum value of 0.80 at 6.16 GHz. Further with increasing value of frequency, permeability increases and peaks at 1.46 at 13.2 GHz. Then its value further decreases sharply to a minimum value of 1.0 at frequency of 15.12 GHz.

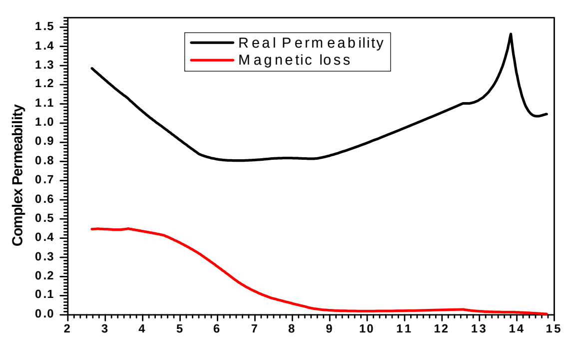

Figure A.7

The magnetic loss decreases from 0.44 at 2.64 GHz to a minimum value of 0.002 at 15.12 GHz.

3.4. Microwave Absorbing Properties:

It is also evident from figure A.8 that the nano-ferrite composite has maximum reflection loss corresponding to different thickness is reported in the table A.2 below:

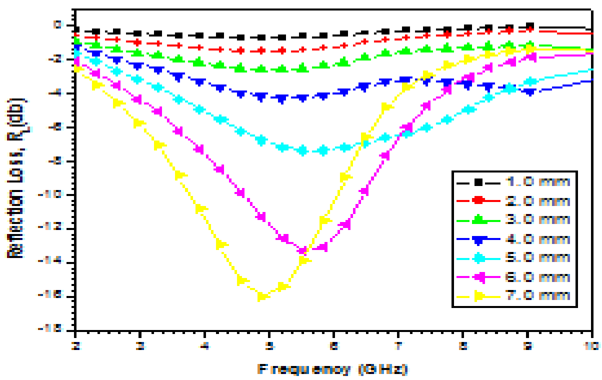

Figure A.8

S.No.	Thickness (mm)	Maximum Reflection Loss (dB)	Matching frequency (GHz)
1.	1.0 mm	0.693	5.2
2.	2.0 mm	1.523	4.88
3.	3.0 mm	2.594	5.2
4.	4.0 mm	4.276	5.2
5.	5.0 mm	7.371	5.52
6.	6.0 mm	13.300	5.52
7.	7.0 mm	16.027	4.88

Table A.2

It is evident from the table A.2 and fig A.9 that the matching frequency is ranging from 4.88 to 5.52 GHz and the maximum reflection loss (dB) is increasing with increasing thickness.

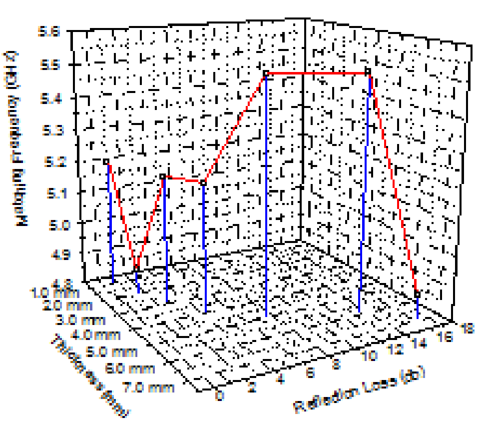

Figure A.9

IV. CONCLUSION

We have studied the microwave absorption properties in the S, C & lower X (8-10 GHz) bands. The maximum reflection losses have been found to increase with increasing thickness. The electromagnetic parameters (ε, μ) are found to vary with applied frequency of microwave. The magnetic & electric tangent loss values confirm that the composition 40% (wt.) gamma ferrite + 20% (wt.) Ni-Zn ferrite in epoxy matrix is lossy in the frequency range 2 to 15 GHz. SEM confirms micro structure of the nano composite. TGA shows composite is thermally stable upto 190 ^{0}C. The nano composite has potential application as a Radar absorbing material, electromagnetic shielding screens, as coatings or jackets and stealth in S (2-4 GHz), C (4-8 GHz) and lower X band (8-10GHz).

ACKNOWLEDGEMENT

The authors thank to Dr. Namburi Eswara Prasad, Sc G, Director DMSRDE, Kanpur for permitting this work. The authors are also thankful to Dr. T.C. Shami and Mr. Himanshu B. Baskey, Sc 'D' of DMSRDE Kanpur for their support in microwave measurements. The author thank to Mr. Sarvesh Kumar, Sc 'F', Mr. AM Singh & Mr. Bharat Patel for their invaluable assistance. The authors also extend their thanks to Prof. (Dr.) Sangeeta Kale, Department of Applied Physics, DIAT Pune for her inspiration and support.

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