Electromagnetic and Microwave Absorption Properties of $Ni_{0.5}\ Zn_{0.5}\ Fe_2O_4$ Nano Ferrite/PU Based Nano-Composite

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Abstract- *Toroidal shaped sample of 40% (by wt.) Ni-Zn ferrite nano powder ($Ni_{0.5}\ Zn_{0.5}\ Fe_2O_4$) loaded in polyurethane (PU) matrix has been successfully prepared. Electromagnetic and Microwave absorption properties of prepared Ni-Zn nano-ferrite ($Ni_{0.5}\ Zn_{0.5}\ Fe_2O_4$)/PU based nano composite have been studied. Simulation study for metal backed single layered absorber has been carried out for examining the electromagnetic (EM) absorbing properties for different thicknesses of the sample. The vector network analyser (Model PNA E8364B, Software module 85071E) attached with coaxial measurement set up has been utilized to investigate the complex permittivity (ε) & permeability (μ). Microwave absorbing properties were investigated by utilizing the measured values of complex permittivity and complex permeability of the absorber in a frequency range of 2 GHz to 18 GHz. Reflection losses (dB) has also been determined for various thicknesses of the composite employing the simulation code for metal backed single layer absorber. SEM and TGA were performed to analyze the morphological and thermal behavior of the nano composite. The complex permittivity and permeability of the nano composite are found to be frequency dependent. Sample has depicted an increase in reflection loss (R_L) with increasing sample thicknesses from t= 1.0 mm, 2.0 mm and 3.0 mm. This nano composite may find applications in EMI shielding for S, C & X band frequencies and medium observable objects.*

Keywords- EMI Shielding, Ferrites, Permittivity, Permeability, dielectric loss tangent, Reflection loss

I. INTRODUCTION

Microwaves have always been an important area of research in electromagnetic interference shielding to minimize the cross-talk among electronic communicating devices, Radar cross section (RCS) reduction for electro-magnetic counter measures and Microwave filters [1, 6, and 7]. In recent times, ferrite based materials have been used as radar absorbing materials in S, C, X and Ku frequency bands & for EMI shielding. Ferrites being ferri-magnetic in nature can tailor the electromagnetic properties of the dielectric matrix materials when selectively mixed in it. Among the numerous electric and magnetic properties exhibited by ferrites based nano-composites, the permittivity (ε) and permeability (μ) are main factors for the designing the radar absorbing materials (RAM) [1, 2]. As per the requirement and applications, RAM are been engineered to get the desired level of RCS reduction, Microwave (MW) absorption or EMI shielding. Recently a lot of attempts have been made to develop various types of nano-ferrite based RAM [2, 3, 4, and 5]. Studies have also been conducted to engineer these parameters towards the development of ferrites based RAMs with significantly larger bandwidth. These are typically 1 mm to 3 mm thick polymeric materials surface, dispersed with magnetic nano particles. It has been seen that ferrites have better EMI suppression properties in the X band frequencies (8-12 GHz) [8]. In this paper, we have reported the electromagnetic and microwave absorption properties of nano Ni-Zn nano ferrite based nano-composite prepared by mixing 40% (wt.) $Ni_{0.5}\ Zn_{0.5}\ Fe_2O_4$ Nano-powder in Poly-urethane matrix. It is observed that this composition may be very useful in EMI shielding for S, C and X band frequencies.

II. MATERIALS AND METHODS

Nano-composite preparation is carried out by using $Ni_{0.5}\ Zn_{0.5}\ Fe_2O_4$ nano-ferrite powder thoroughly mixed using acetone medium in two pack polyurethane matrix consists of polyol-8 (Ciba-Geigy, Switzerland) and hexamethylene di-iso-cynate (E Merck, Germany) mixed in 50–50 ratios. 40% (by wt) $Ni_{0.5}\ Zn_{0.5}\ Fe_2O_4$ nano-ferrite was mixed in PU. The mixture was homogenized in mortar and pestle and then put in the mould followed by curing it under heat and pressure in a hydraulic press. The sample was prepared in toroidal shape with an outer diameter of 7.0 mm, an inner diameter of 3.0 mm to fit in co-axial waveguide sample holder.

III. MICROWAVE MEASUREMENTS

Electromagnetic parameters (complex permittivity and Complex permeability) of composite were investigated using AGILENT vector network analyser Model PNA E8364B for the frequency range of 2 GHz to 18 GHz. The frequency dependence of permittivity (ε’, ε”) and permeability (μ’, μ”) for $Ni_{0.5}$ $Zn_{0.5}$ Fe_2O_4 Nano-ferrite PU composite are shown in Figure 1. From 2-14 GHz i.e. till 14 GHz the ε’ remains constant and at higher frequency (15-18 GHz) the dielectric constant (ε’) increases probably due to the ferrimagnetic nature of Ni-Zn ferrite filler. The dielectric loss component (ε”) is nearly negligible hence there is no absorption of Micro-waves. The ε” is defined as ε” = σ/ω, as this composition is ferrimagnetic insulating because the dielectric loss component (ε”) is nearly zero hence conductivity is nearly negligible. In transient EM field the Ni-Zn Ferrite sample exhibits the relation given by the equation:

$$\varepsilon = \varepsilon' - j\varepsilon'' \qquad (1)$$

ε’ = Real part of ε i.e. Di-electric constant

ε”= Imaginary part of ε i.e. electric loss component

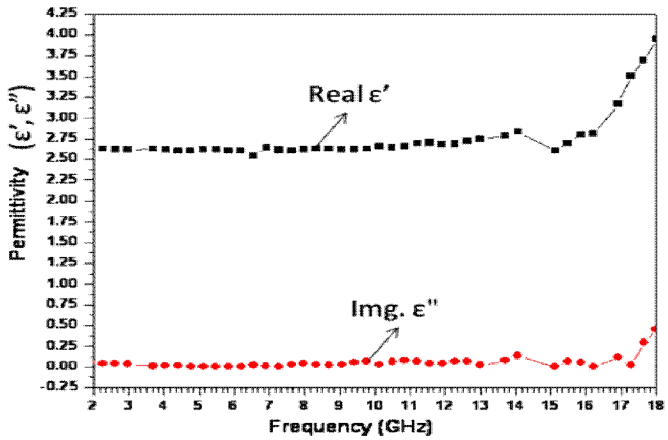

Figure 1: Complex Permittivity vs. Frequency variation

The electrical tangent loss is given by tan δ_e = ε”/ ε’. The tan δ_e is the ratio of energy loss per unit radian in the dielectric to the energy stored in the dielectric and its frequency dependent variation is shown in the figure 2 below:

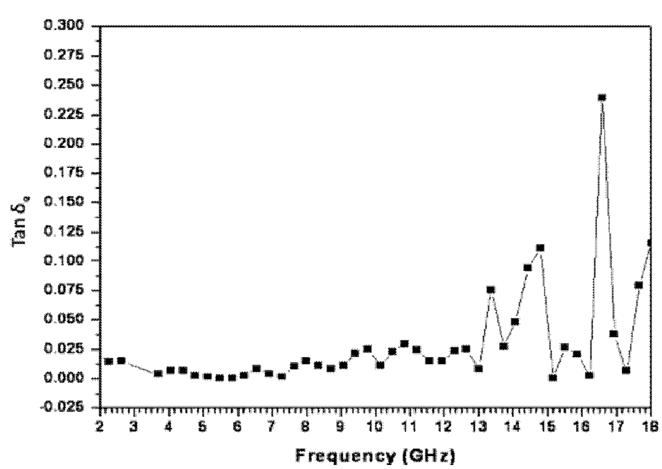

Figure 2: Di-electric tangent loss (tan δ_e) vs. Frequency (GHz) variation

From the values of ε’ and ε”, it is expected that Ni-Zn Ferrite gives good Electro-magnetic properties in S, C and X band frequencies.

$$\varepsilon = \varepsilon'\left(1 - j\frac{\varepsilon''}{\varepsilon'}\right) \qquad (2)$$

$$\varepsilon = \varepsilon'\left(1 - j\tan\delta_e\right) \qquad (3)$$

It is evident from the figure 2, all the values of tan δ_e w.r.t. frequencies (GHz) shows that tan δ_e is positive valued and hence the ε also varies with according to the equation (3).

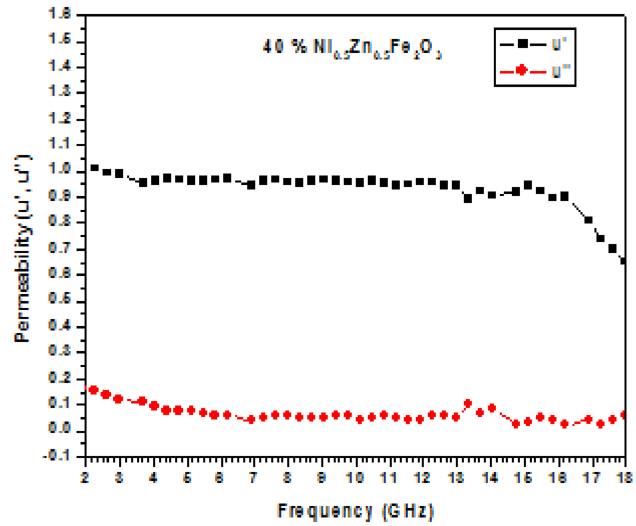

Figure 3: Complex Permeability vs. Frequency (GHz) variation

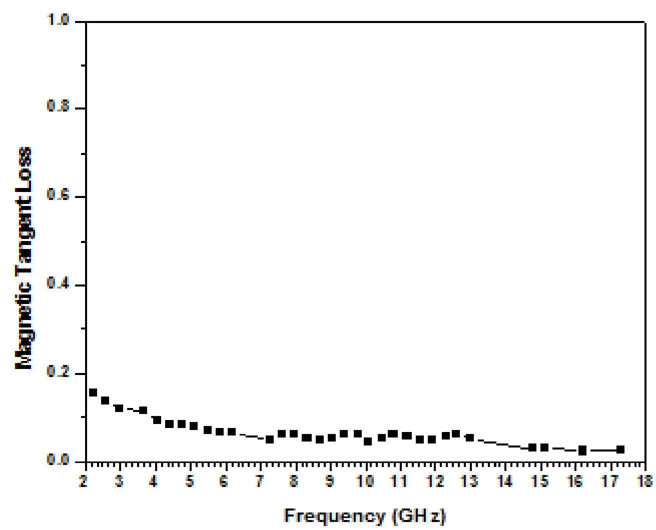

Figure 4: Magnetic tangent loss (tan δ_m) vs. Frequency variation

Figure 3 shows that the variation of the complex permeability with frequency (GHz). There is negligible magnetic loss as u’’ is nearly negligible with frequency. From figure 4, it is evident that the magnetic tangent loss (tan δ_m)

gradually decreases with frequency (GHz). Hence there is gradual decrease in magnetic loss with increasing frequency.

The reflection loss (dB) of the prepared nano-composite sample for various sample thickness has been calculated using experimentally obtained values of ε_r and μ_r for single layer metal backed condition. The reflection loss for a particular thickness (t) is frequency dependent as well as electromagnetic parameters (ε, μ) dependent and is given by the equations 4 and 5 below:

$$Z_{in} = \sqrt{\frac{\mu_r}{\varepsilon_r}} \tanh\left[j\left\{\frac{2\pi ft}{c}\right\}\left\{\sqrt{\mu_r.\varepsilon_r}\right\}\right] \quad (4)$$

$$R_L\left(dB\right) = 20\log\left|\frac{Z_{in}-1}{Z_{in}+1}\right| \quad (5)$$

where Z_{in} is the normalized impedance of the air-absorber interface layer, c is the speed of light, f is the frequency of EM wave respectively.

Further, it is self evident from the figure 5, the reflection loss (dB) is almost constant for various absorber thicknesses in the S (2-4 GHz), C (4-8 GHz) & X (8-12 GHz) band frequencies. Thus it is a potential EMI shielding material in these frequency bands.

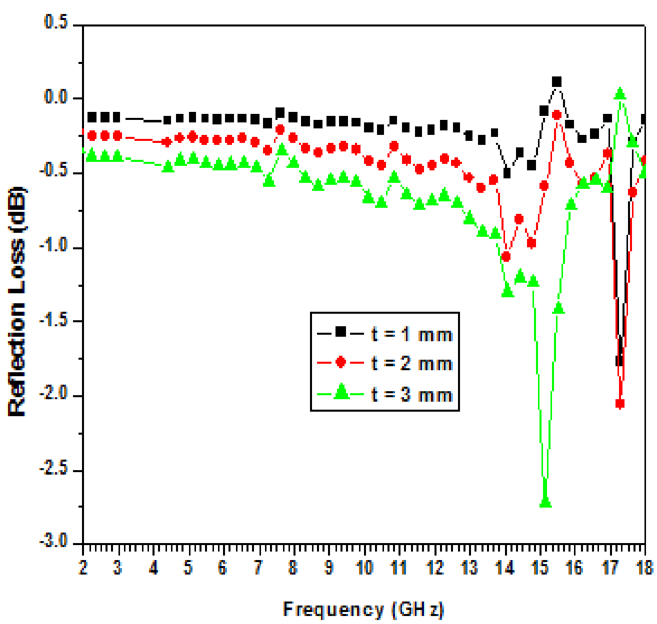

Figure 5: Reflection loss (dB) vs. Frequency (GHz) variation

The reflection loss at matching frequency increases along-with the increasing matching thickness as shown in the figure 6.

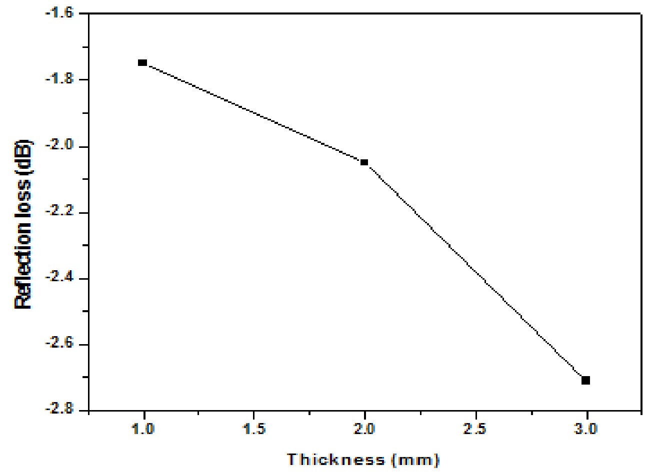

Figure 6: Maximum Reflection loss ($R_{L,\ max}$) vs. thickness (mm)

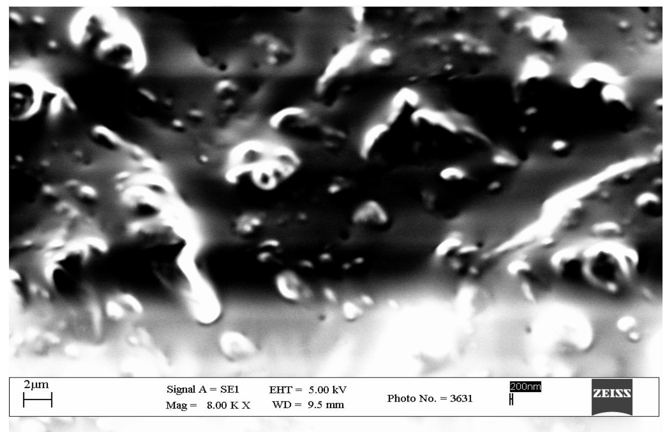

Figure 7: SEM of 40% (by wt.) $Ni_{0.5}Zn_{0.5}$ Fe_2O_4 Nano powder in PU

The figure 7 shows the SEM of NiZn Ferrite. It is illustrated from the figure that NiZn ferrite ($Ni_{0.5}$ $Zn_{0.5}$ Fe_2O_4) filler is dispersed non-uniformly in a form of spherical nano-particles embedded in PU matrix.

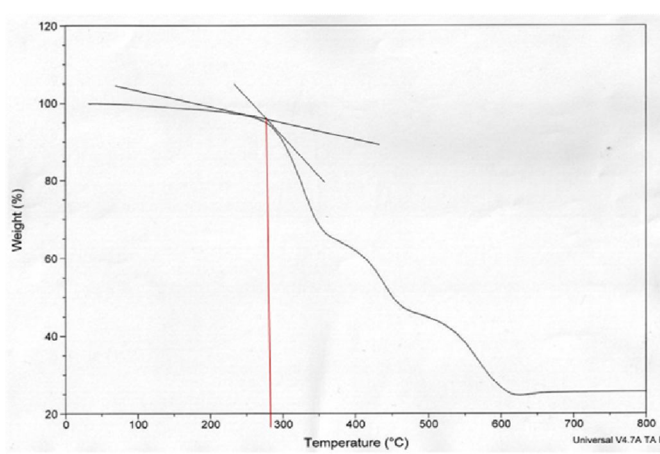

Figure 8: Thermo gravimetric analysis of $Ni_{0.5}Zn_{0.5}$ Fe_2O_4 nano composite

Thermo gravimetric analysis (TGA) has been carried out to study the thermal stability of the prepared nano-ferrite sample. Figure 8 shows the TGA plot of prepared nano-ferrite which exhibits weight loss in several steps. But the prepared nano-ferrite is found to have a thermal stability at least up to 280 ^{0}C.

IV. CONCLUSION

We have successfully prepared the NiZn Ferrite /PU based torroidal shaped nano-composite. The nano ferrite have been found thermally stable upto 280 ^{0}C. This Ram has particular matching frequency at a particular thickness. Thus these NiZn Ferrite /PU based nano-composite ferrite can be used for EMI shielding & medium observable objects.

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