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Microwave Absorption Properties of Ni-Zn Ferrite Nano-Particle based Nano Composite

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ABSTRACT: Toroidal shaped sample of particulate composite with 30% (by wt.) Ni-Zn nano-ferrite loaded in polyurethane (PU) matrix has been successfully prepared. Microwave absorption properties of prepared Ni-Zn ferrite based nano composite have been studied. Simulation study for metal backed single layered absorber has been carried for probing the electromagnetic (EM) absorbing properties for different thicknesses of the samples. The vector network analyser (Model PNA E8364B, Software module 85071E) attached with coaxial measurement set up has been utilized to investigate the complex permittivity & permeability. Microwave absorbing properties were investigated by utilizing the measured values of complex permittivity and complex permeability of the absorber in a frequency range of 110 MHz to 18 GHz. Reflection loss (dB) has also been determined for various thicknesses of the composite employing the simulation code. SEM and TGA were performed to analyse the morphological and thermal behaviour of the nano composite. The complex permittivity and permeability of the nano composite are found to be frequency dependent. Sample has depicted increasing reflection loss (RL) from -7.95 dB to -12.93 dB at same matching frequency centred at 12.27 GHz against the sample thicknesses of 1.0 mm, 2.0 mm and 3.0 mm. This nano composite may find applications in narrow frequency microwave absorbers and EMI shielding.

KEYWORDS: Nano composite, RAM, Nano-ferrite, RCS, EMI shielding, Reflection loss, Microwave absorber.

I. INTRODUCTION

Radar absorbing materials (RAM) have been identified as important class of materials in the scientific community since World War II, parallel to the first introduction of RADAR detection, as counter measure to RADAR detection by virtue of its strong absorbency [1-3]. EMI/ EMC are also an area where RAM founds its wide applicability to improve the performance of the system under noisy EM environment [4-6]. Recent advents in material science and engineering have evolved several novel materials whose electromagnetic (EM) properties make them ideal candidates for use as radar absorbing materials (RAM). These new types of RAM materials can be applied as very thin layers and still maintain their absorption effectiveness making them ideal for radar cross section (RCS) reduction on aircraft, bridges, ships, and other structures [5-6].

Depending upon their application and ease of implementation RAM are been engineered to get the desired level of absorption. Recently plethora of attempt have been made to develop various types of ferrite based RAM [7]. It has been seen that ferrites have better EMI suppression properties. There are numerous electric and magnetic properties exhibited by ferrites and among those, the permittivity (ε) and permeability (μ) are key factors for the RAM designing [7-10]. Additionally, studies have also been conducted to engineer these parameters towards the development of ferrites based RAMs with significantly larger bandwidth. These are typically 0.1 mm to 3 mm thick polymeric materials surface, dispersed with magnetic particles [11].

In principle, high permeability (magnetic loss properties) and high permittivity (dielectric loss properties) enables Ni-Zn ferrite based RAM for phenomenally good absorption at very high frequencies (GHz) [4, 8-10] and in lesser thicknesses. Such microwave absorbing ferrites can be potential candidate to mitigate the EMI/EMC issues and provide passive counter measures against the operational enemy RADARs in military aircraft and unmanned aerial vehicles at phenomenal wider range of operations.

The presented paper calls for preparation of Ni-Zn nano-ferrite based composites samples of varying thickness and their performance evaluation for EM and microwave absorption properties.

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II. EXPERIMENTAL

A. Materials and method of synthesis

Composite preparation is carried out by using Ni-Zn 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. 30% (by wt) Ni-Zn 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. 30% (by wt) Ni-Zn nano-ferrite was mixed in PU and prepared in toroidal shaped with an outer diameter of 7.0 mm, an inner diameter of 3.0 mm to fit in co-axial waveguide sample holder.

B. 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 for the frequency range of 11 MHz to 18 GHz.

Further, the reflection loss (R_L) with different thicknesses (t) have been derived from equations (1) and (2) given below [7]:

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

$$Z_{in} = \left(\frac{\mu_r}{\varepsilon_r}\right)^{\frac{1}{2}} \tanh\left[j\left(\frac{2\pi fd}{c}\right)(\mu_r\varepsilon_r)^{\frac{1}{2}}\right] \quad (2)$$

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.RESULT AND DISCUSSION

A. Morphological Properties

The SEM of neat PU and Ni-Zn ferrite Nano-particles distribution in PU is shown in figure1 (a) and 1(b) respectively. The phase evolution of Ni-Zn Nano Ferrite particles (figure 1 (b)) shows amorphous distribution of Ni-Zn nano-ferrite particles in PU.

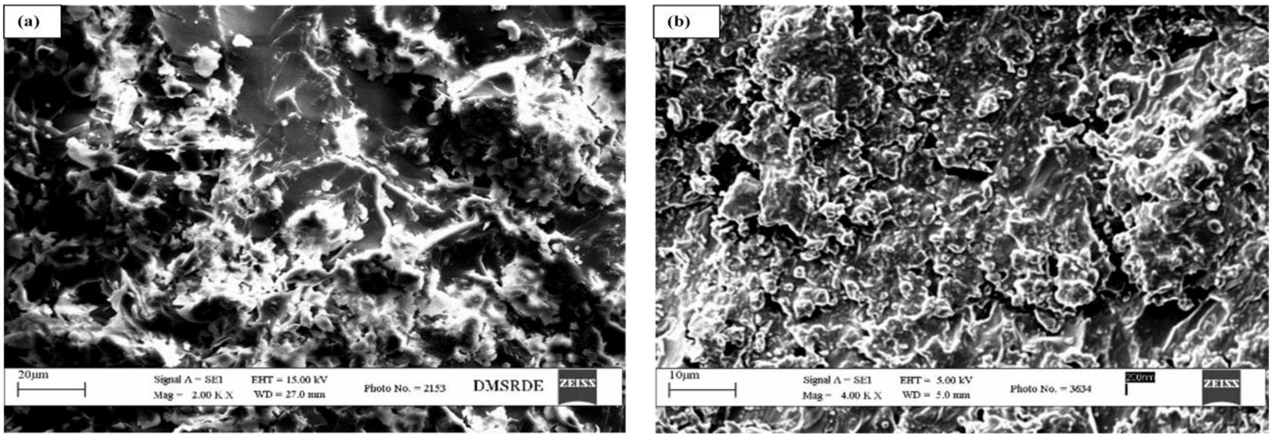

Fig. 1. Scanning Electron Microscope Image (a) Polyurethane (PU) (b) Ni-Zn Nano-Ferrite PU Composite

B. **Thermal Properties**

Thermo gravimetric analysis (TGA) has also been carried out to study the thermal stability of the prepared nano-ferrite composite. Figure 2 shows the TGA plot of prepared nano-ferrite composite which exhibits weight loss in several steps. But the prepared nano-ferrite composite is found to have a thermal stability at least up to 270 ^{0}C.

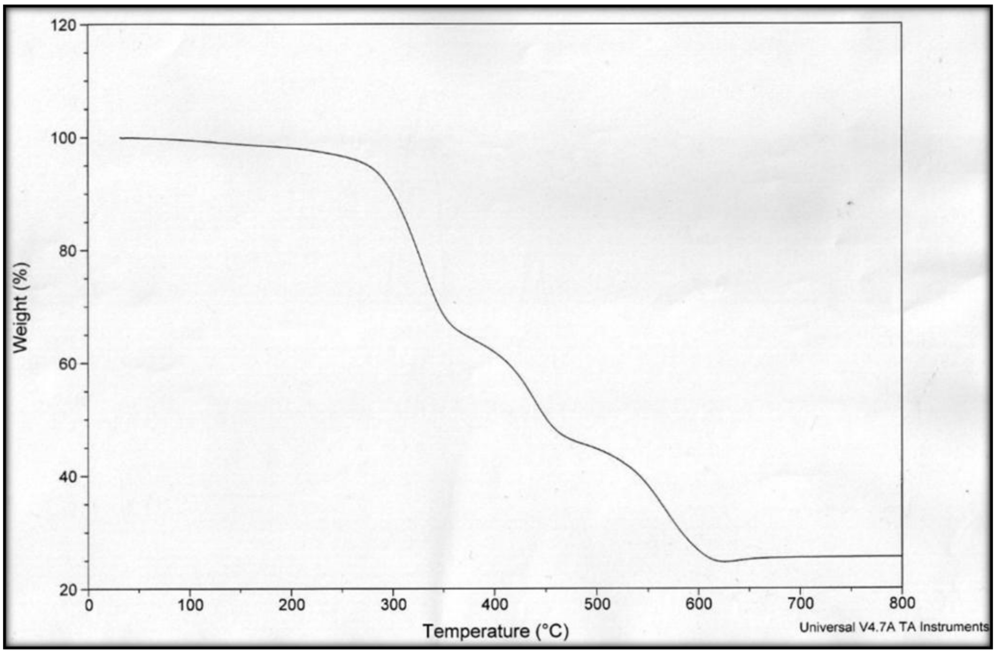

Fig. 2. TGA of Ni-Zn Ferrite (30% by wt) sample

C. **Permittivity Spectra & Permeability Spectra**

The electromagnetic parameters (ε', ε", μ' and μ") of Ni-Zn nano-ferrite are shown in the figure 3 (a) and figure 3(b). The figure 3(a) shows the complicated behaviour of the permittivity ε (ε', ε") with frequency with a zero dielectric loss at 13 GHz for 30wt % of Ni-Zn nano-ferrite in PU matrix. The insert of figure 3(a) shows linearly increasing behaviour of permittivity (ε) with frequency in 14-18 GHz.

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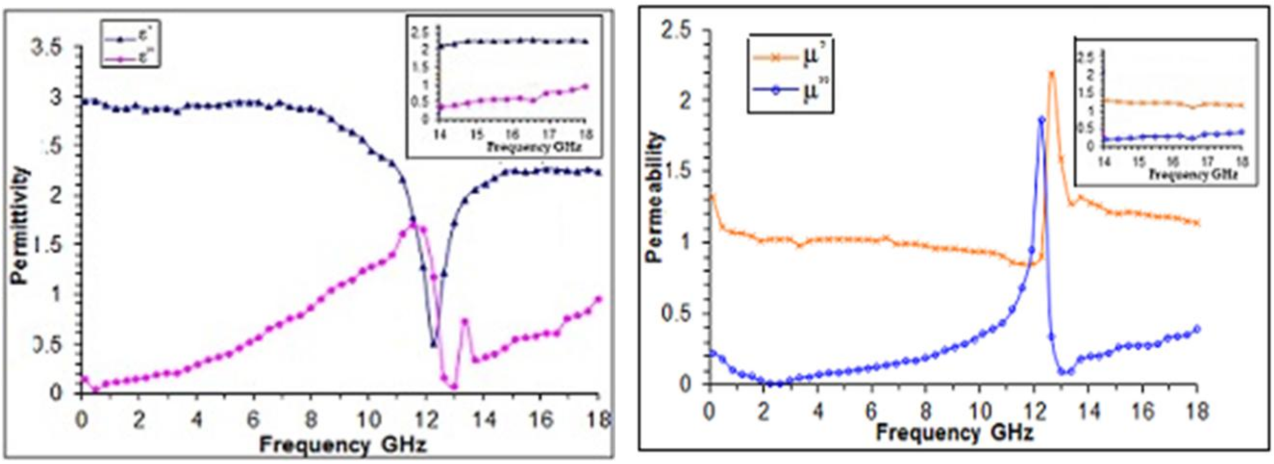

(a) (b)

Fig. 3. Variation of (a) permittivity ε (ε' and ε") (b) permeability μ (μ' and μ") with frequency (GHz) for Ni-Zn Nano-ferrite based PU Nano-Composite

Figure 3(b) shows the variation of permeability μ (μ' and μ") with frequency for Ni-Zn Nano ferrite.

The figure 3(b) insert shows that the real part of permeability (μ') decreases with increasing frequency while the magnetic loss i.e. imaginary part of permeability (μ") increases with increasing frequency in 14-18 GHz because of Ni-Zn Nano ferrite filler.

D. **Microwave absorbing properties**

The reflection loss (dB) of the prepared Ni-Zn nano-ferrite based nano composite sample having 30% (by wt.) Ni-Zn nano-ferrite in polyurethane (PU) matrix for various thicknesses (t=1.0, 2.0 and 3.0 mm) have been calculated using experimentally obtained values of ε_r and μ_r.

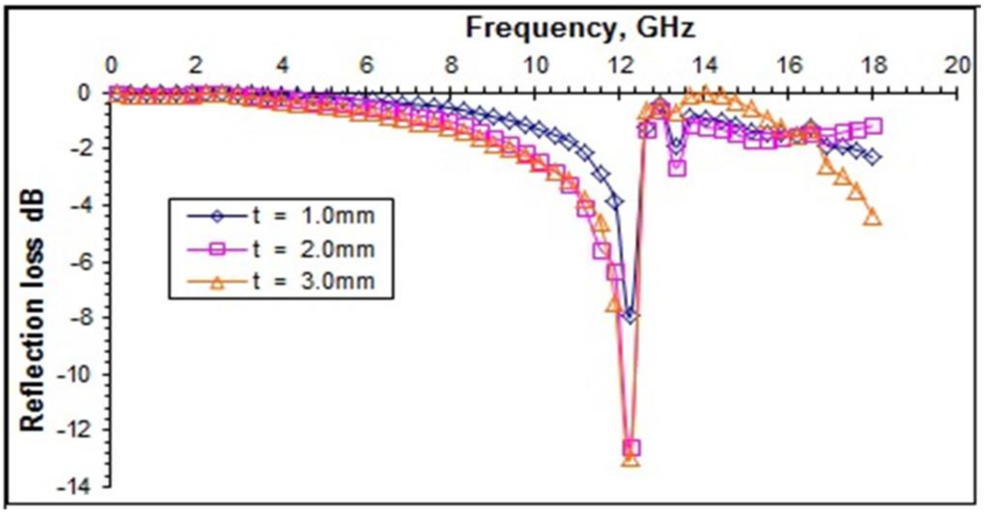

Fig.4. Variation of Reflection loss (dB) with Frequency (GHz) for thicknesses t=1.0 mm, 2.0 mm and 3.00 mm

Figure 4 depicts the variation of the reflection loss (dB) with frequency in the range of 0.11GHz - 18 GHz. The maximum reflection loss observed for thicknesses are shown in the table 1.

Thickness (t) (mm)	Matching frequency (f_m) (GHz)	Reflection loss (R_L) (dB) at matching frequency (f_m)	% increase in reflection loss (R_L) with thickness (t)
1.0	12.2752	-7.95	--
2.0	12.2752	-12.56	57.98 (in dB) from 1mm to 2.0 mm
3.0	12.2752	-12.93	2.94 (in dB) from 2 mm to 3.0 mm

Table 1

The reflection loss (R_L) is increased by 57.98 % at matching frequency for increase of thickness from 1.0 mm to 2.0 mm, however with increasing thickness to t=3.0 mm, there is steep elevation of 2.94% in reflection loss (R_L) i.e. from 12.56 dB to -12.93dB is observed as shown in table 1.

IV. CONCLUSION

Ni-Zn Ferrite based nano composites in polyurethane matrix has been successful prepared. The complex relative permittivity & permeability spectra and their relationship with microwave absorbing properties have been investigated. It is observed that maximum reflection losses was shown at matching frequency centred at 12.27 GHz for all the samples with different thickness as mentioned in table-1. Reflection loss of >12 dB was observed at 12.27 GHz with the bandwidth of 716 MHz (12.633 GHz - 11.917 GHz) for 2.0 and 3.0 mm thicknesses. Prepared material may be utilized for EMI shielding and stealth applications.

V. ACKNOWLEDGEMENT

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