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# Microwave Absorption Properties of Carbon Black Nano-filler in PU based Nano-Composites

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**ABSTRACT**: Toroidal shaped composite samples having Carbon black nano powder (CBP) as filler with varying weight contents (100, 150, 200, 300 and 400 mg in 1 ml PU) thoroughly mixed in Poly-urethane (PU) matrix have been successfully prepared. Microwave absorption properties (stealth properties) of prepared 400 mg CBP/PU nano-composite have been studied. Simulation studies for metal backed single layered absorbers have been carried out for studying 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 and permeability. Microwave absorbing properties were examined by utilizing the measured values of complex permittivity and complex permeability of the absorber in the frequency range of 2 GHz to 18 GHz. Reflection loss $R_L$ (dB) vs. frequency variation have been also determined for various thicknesses (t=5.0, 6.0 and 7.0 mm) 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 permittivities of the nano-composites are found to be frequency dependent. Higher reflection loss ($R_{L,}$ dB) have been reported in X (higher frequency side) , Ku (lower frequency side) and Ku (higher frequency side) band for the sample thicknesses of 5.0 mm, 6.0 mm and 7.0 mm respectively.

**KEYWORDS**: Radar Absorbing Materials, Reflection loss, Microwave absorber, RCS, Permittivity and Permeability.

## I. INTRODUCTION

Radar absorbing materials have much been initially applied for low observable objects and further has been applied for stealth technologies [1]. During the World War II, parallel to the introduction of the RADAR as a technological aircraft detection system, stealth was introduced as a counter measure to it [2]. Stealth can be achieved by employing various techniques as by Geometry (Radar Absorbing Structures) [3], Active loading [4], Passive loading [5], distributed loading (Broad band) [6]. For stealth, Radar Cross Section (RCS) has to be minimized [7] and the above techniques have been proven to be effective. Many researchers have worked on development of Microwave absorbing materials [8-9]. Currently, Abbas et al. are working on Carbon black and MWCNT filler based PU nano-composites since 2005 [10]. Microwave absorption properties of Carbon based Conducting nano-composites have been studied and published [11-13]. In this present paper, we are discussing some more aspects of the Carbon black powder (CBP) filler in thermoplastic Poly-urethane matrix based nano-composites.

## II. EXPERIMENTAL

### A. Materials and method of synthesis

Nano-composite preparation is carried out by using Carbon black powder (CBP) (Senka Carbon, India) 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. Samples with carbon black powder (CBP) as filler with varying weight contents (100, 150, 200, 300 and 400 mg) mixed in 1 ml polyurethane (PU) matrix have been prepared. The mixture was homogenized and then put in the mould followed by curing it under heat and pressure in a

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hydraulic press. The samples were 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 in the frequency range of 2–18 GHz.

The reflection loss ($R_L$) with different thicknesses (t) have been calculated by utilising the well established equations (1) and (2) given below:

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

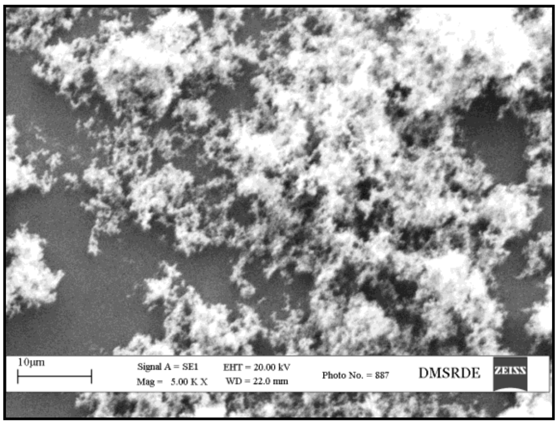
$$Z_{in} = \left( \frac{\mu_r}{\varepsilon_r} \right)^{\frac{1}{2}} \tanh \left[ j \left( \frac{2\pi f t}{c} \right) (\mu_r \varepsilon_r)^{\frac{1}{2}} \right] \qquad \text{............(2)}$$

where $Z_{in}$ is the normalized input impedance at free space and material interface, $\varepsilon_r = \varepsilon' - j\varepsilon''$ and $\mu_r = \mu' - j\mu''$ are the complex permittivity and permeability respectively 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, t is the thickness of the absorber, and c and f are the velocity of light and the frequency of microwave in free space, respectively.

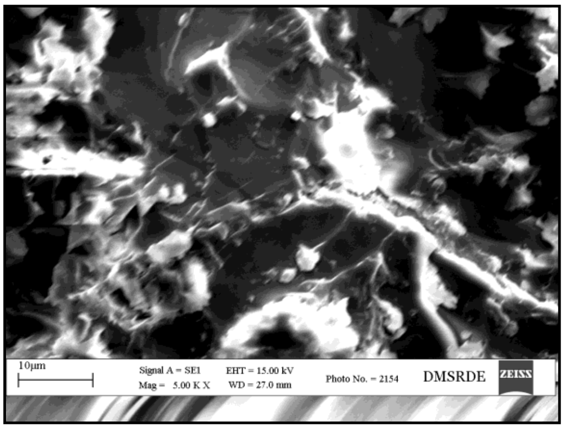
## III. RESULT AND DISCUSSION

### A. Morphological Properties

The surface morphologies have been studied with the help of Scanning Electron Microscope (SEM) images. The SEM images of carbon black nano-particles and polyurethane (PU) are shown in figure1 (a) and 1(b) respectively.




1(a)




1(b)

Fig. 1. Scanning Electron Micrographs (a) Carbon Black Powder (CBP) (b) SEM of Poly Urethane (PU)

SEM micrograph 1(a) shows that the carbon black particles are agglomerated and forms the porous structure. Figure 1(b) shows the rubberised nature of virgin polyurethane (PU) matrix.

### B. *Thermal Properties*

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Thermo gravimetric analysis (TGA) has also been carried out to study the thermal stability of the prepared nano-composite. Figure 2 shows the TGA plot of prepared nano-composite which exhibits weight loss in several steps. But the prepared CBP/PU nano-composite is found to have a thermal stability at least up to 300 $^{0}$C.

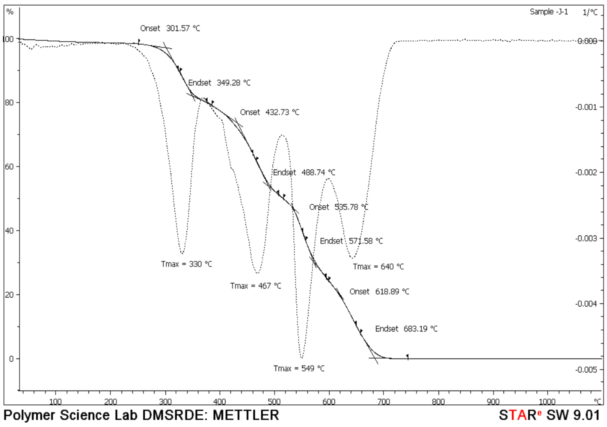
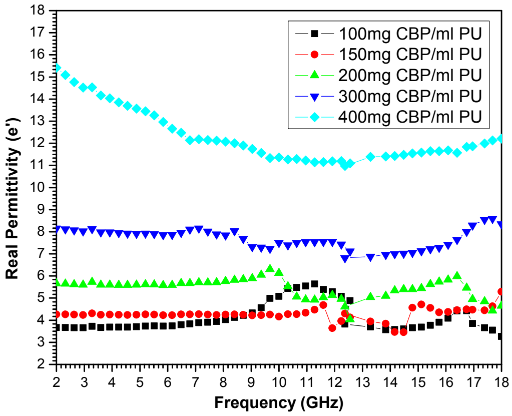


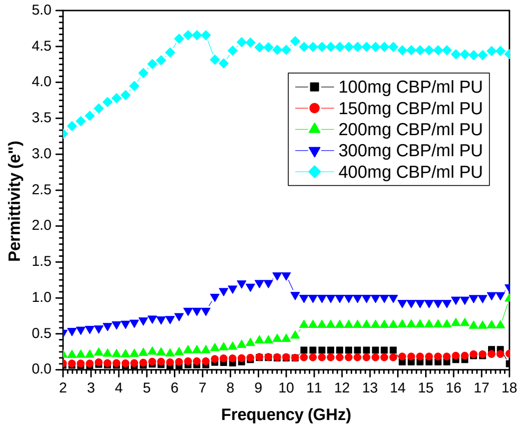

Fig. 2. TGA of 400 mg Carbon Black/ ml PU Nano-composite

## C. Permittivity Spectra and Permeability Spectra

The dielectric parameters (ε', ε") of CBP/PU nano-composites are shown in the figure 3 (a) and figure 3(b). The figure 3(a) shows that the dielectric constants (ε') of the prepared CBP/PU nano-composite samples are frequency dependent and also varies with the weight contents of the conducting CBP filler.




3(a)




3 (b)

Fig. 2. Variation of the (a) Dielectric constant (ε') with frequency (GHz) (b) Dielectric Loss (ε") with frequency (GHz) of CBP/PU Nano-composite

The figure 3(b) shows that the dielectric loss (ε") is increasing with increasing CBP filler content in the composite.

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Figure 4 shows the real permeability (μ') is nearly frequency independent in 2-18 GHz. The magnetic loss for all the samples have been found nearly zero (not shown) because of the conducting nature of the samples.

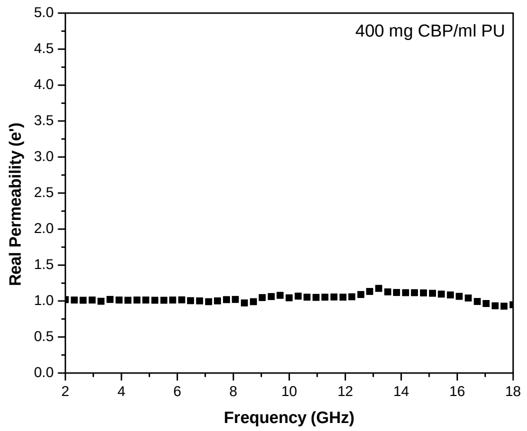


Fig. 3. Variation of Real permeability (μ') with frequency (GHz) of CBP/PU Nano-composite

D. **Microwave absorbing properties**

The reflection loss (dB) of the prepared CBP/PU nano-composite sample having 400 mg (by wt.) in 1ml PU matrix for various thicknesses (t=5.0, 6.0 and 7.0 mm) have been calculated using experimentally obtained values of $\varepsilon_r$ and $\mu_r$.

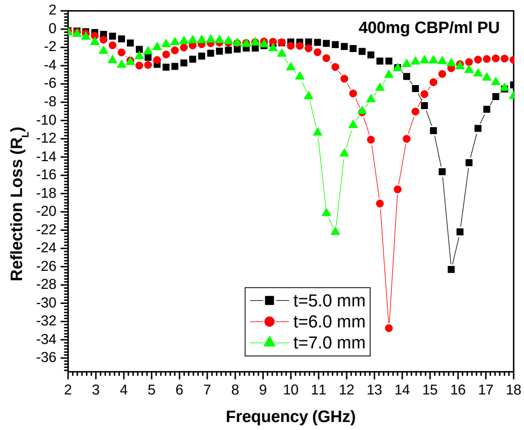


Fig. 4. Reflection loss ($R_L$, dB) vs. frequency (GHz) for t= 5, 6 and7 mm

Figure 4 depicts the variation of the reflection loss (dB) with frequency of 400 mg CBP/ml PU nano-composite in the frequency range of 2 GHz - 18 GHz. The maximum reflection loss observed for thicknesses are shown in the table 1.

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| Thickness (t) (mm) | Matching frequency ($f_m$) (GHz) | Max. Reflection loss ($R_{L,}$ max) (dB) at matching frequency ($f_m$) | Frequency band for Reflection loss ($R_L$) > 90% (i.e. more than10 dB) | Relevant Band |
|---|---|---|---|---|
| 5.0 | 15.76 | - 26.31 | 10.96GHz - 11.74 GHz | X (higher frequency) |
| 6.0 | 13.52 | - 32.74 | 12.88 GHz - 14.16 GHz | Ku (lower frequency) |
| 7.0 | 11.60 | - 22.22 | 15.12 GHz -16.72 GHz | Ku (higher frequency) |

Table 1: Reflection loss (dB) with various thickness (t)

## IV. CONCLUSION

100, 150, 200, 300 and 400 mg CBP filler based nano-composites in 1 ml polyurethane matrix has been successful prepared. The complex relative permittivity and permeability spectra and their relationship with microwave absorbing properties of 400 mg CBP/ml PU nano-composite have been investigated in detail. The maximum reflection loss ($R_{L,}$ max) of 32.74 dB have been obtained at a matching frequency of 13.52 GHz for sample at thickness of 6.0 mm as mentioned in table-1. Prepared material may be utilized for EMI shielding and stealth applications.

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