

## COMPOSITE MATERIALS FOR ELECTROMAGNETIC SHIELDING

Ionut BALAN<sup>1</sup>, Cristian MORARI<sup>2</sup>, Alexandru Eros PATROI<sup>3</sup>

*Nowadays, composite materials are often used instead of metallic shields due to their good mechanical properties and corrosion resistance. This paper investigates the electromagnetic shielding capabilities of composite materials consisting of Ni and Fe powders embedded in a polymer matrix. The shielding effectiveness is determined by using the free space method in the frequency range of 0.9 GHz - 4 GHz. The materials preparation procedure is also described. Two material samples are considered along with some combinations between them and a carbon mesh. The obtained results indicate poor shielding performance of Ni and Fe based samples and an improved performance when the carbon mesh is involved.*

**Keywords:** electromagnetic shielding, composite materials, metallic powder

### 1. Introduction

The use of composite materials is becoming increasingly important in modern technologies due to their mechanical and electrical properties, low weight, and corrosion resistance. The possibility to adapt these properties to operating condition, by combining features from different constituents, is also a benefit of composite materials. There are many types of composite materials with various applications, like mechanical support, electromagnetic shielding, and heat transfer [1 - 5].

The composite materials have been developed in the aerospace industry, in the need to control and improve the properties of the materials in accordance with the established requirements. Composite materials consist of two or more different constituents and have properties which cannot be achieved by any individual constituent [1, 2, 6].

This paper focuses on composite materials made of silicon rubber filled with conductive powders, in particular Ni and Fe powders, and on their electromagnetic shielding performances. Moreover, a carbon mesh is used as

<sup>1</sup> National Institute for Research and Development in Electrical Engineering ICPE-CA, Bucharest, Romania, e-mail: ionut.balan@icpe-ca.ro

<sup>2</sup> National Institute for Research and Development in Electrical Engineering ICPE-CA, Bucharest, Romania, e-mail: cristian.morari@icpe-ca.ro

<sup>3</sup> National Institute for Research and Development in Electrical Engineering ICPE-CA, Bucharest, Romania, e-mail: eros.patroi@icpe-ca.ro

separate layer for improving the overall shielding effectiveness of prepared composite material samples.

## 2. Experimental

### 2.1 Composites preparation

Three samples were prepared by filling a dielectric matrix with Ni and Fe powders as conductive fillers. As dielectric matrix a two components silicon elastomer was used, which hardens at room temperature by a polycondensation reaction. The fillers were previously dried in an oven to eliminate hygroscopic humidity. First, the silicone rubber and fillers were weighted and mixed for homogenization (about 15 minutes) then the catalyst was added and mixed for another 15 minutes. The composite was stretched by a technique similar with doctor blade technique [10, 11].

Sample 1, consists of a compound with silicon rubber filled with Ni powder (20 wt %) and Fe powder (20 wt %) which was stretched over a carbon mesh. The carbon mesh is commercially available and is characterized by a good conductivity, oxidation resistance and thermal stability. Sample 2 contains silicon rubber filled with 20 wt % Fe powder and Sample 3 contains silicon rubber with 20 wt % Ni powder, both without carbon mesh. All samples have 300 mm x 210 mm in size and 2 mm thickness.

### 2.2. Electromagnetic Shielding Measurement

The free space transmission method was used in order to determine the shielding effectiveness (SE) of samples. For this, two horn antennas placed in an anechoic chamber and a vector network analyzer were employed (Fig. 1). The samples were placed between antennas at a distance of 0.3 m from each antenna, in the far field zone. The frequency was scanned between 900 MHz and 4 GHz.

For determining the shielding effectiveness of a sample, two measurements must be done. First the emitted signal is measured without sample between antennas and then the sample is placed and the signal transmitted through sample is measured. The incident signal and the distance between antennas are maintained at the same values for both measurements. Shielding effectiveness, in decibels, is calculated using the following relation [7, 8, 9]:

$$SE_{dB} = 10 \log \left( \frac{P_i}{P_t} \right) \quad (1)$$

where  $P_i$  and  $P_t$  are the incident field power, respective power of the field transmitted through sample.

By using vector network analyzer, this is a straightforward operation since the analyzer is able to store the data from reference measurement (without sample) and automatically calculate shielding effectiveness when placing sample between antennas.

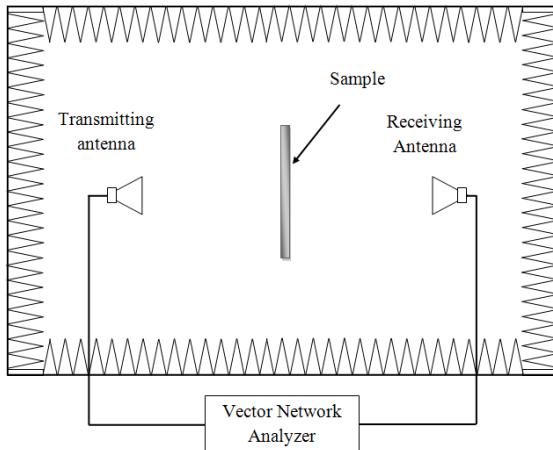


Fig. 1. Experimental test setup for determining shielding effectiveness

### 3. Results

The three prepared samples were tested for electromagnetic shielding effectiveness in the 0.9 - 4 GHz frequency range. In addition, a sandwich made of Sample 1 plus Sample 3 and the carbon mesh alone were tested in the same frequency range. The obtained results are presented in Figs. 2, 3, 4, 5, and 6.

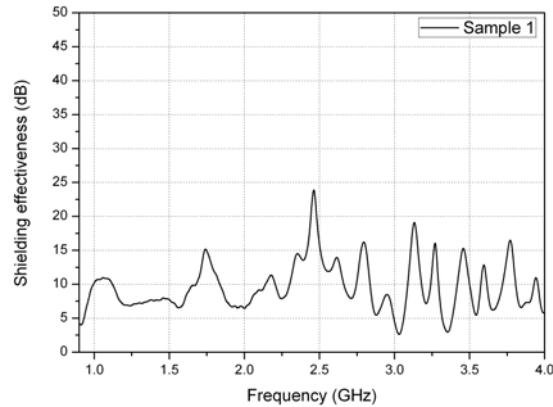


Fig. 2. Shielding effectiveness of Sample 1

Sample 1 (Fig. 2) shows a shielding effectiveness with an average value of about 10 dB. Samples 2 and 3 (Fig. 3 and 4), with Fe respectively Ni as fillers, do not show any attenuation of the electromagnetic waves. These results suggest that the attenuation of the electromagnetic waves showed by Sample 1 is due to the carbon mesh.

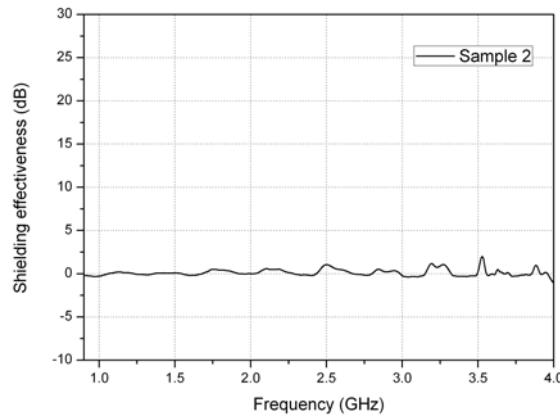


Fig. 3. Shielding effectiveness of Sample 2

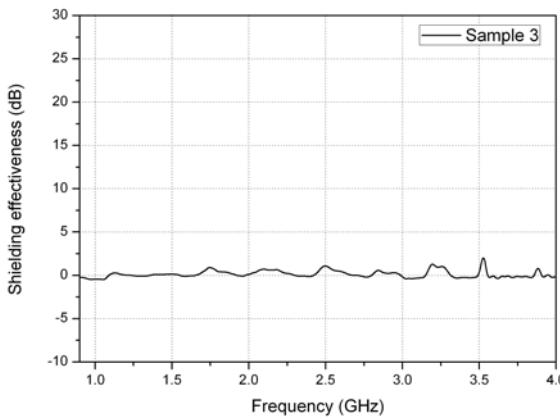


Fig. 4. Shielding effectiveness of Sample 3

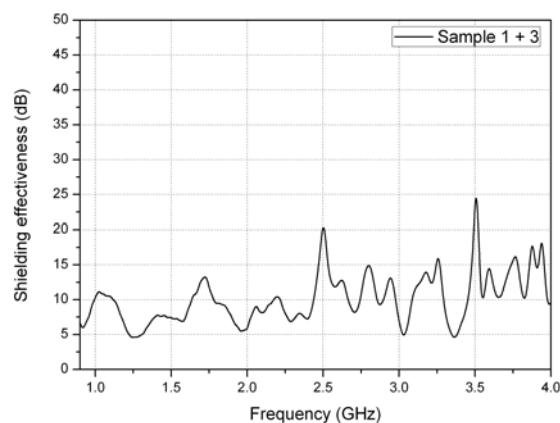


Fig. 5. Shielding effectiveness of Sample 1 + Sample 3 sandwich

The SE of Sample 1 (Fig. 5) did not improved when Sample 3 was stacked on it but it kept the average value of about 10 dB.

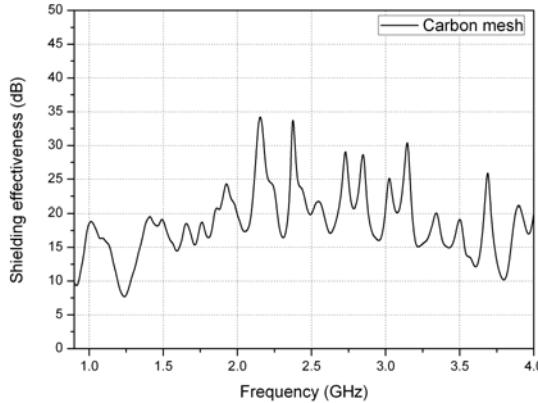


Fig. 6. Shielding effectiveness of carbon mesh

The carbon mesh (Fig. 6) exhibits a SE even better than Sample 1 with an average value of about 20 dB in the 2.2 – 3.2 GHz frequency range. This result actually proves the fact that the attenuation provided by Sample 1 is only given by the carbon mesh. Also, it suggests that the main attenuation mechanism is reflection on carbon mesh, which is a good conductor. In this respect, the results of Sample 1 also indicate that the concentration of Fe and Ni fillers is too low to contribute to reflection losses and that the composite material lowered the overall conductivity of Sample 1. By increasing the conductive fillers concentration, is likely to obtain a better shielding capability of composite materials.

#### 4. Conclusions

The present paper reports the results of shielding effectiveness (SE) obtained for several samples containing composite materials based on Ni and Fe powders and a carbon mesh. The obtained results revealed a poor shielding performance of the Ni and Fe based prepared samples and demonstrated the capability of carbon mesh to work as electromagnetic shield in the 0.9 - 4 GHz frequency range. An increase of the conductive fillers concentration is recommended in order to obtain composites with shielding properties. Such composites could be used, alone or in combination with another material (like carbon mesh), for shielding purposes in applications that require, besides electromagnetic shielding, flexibility and corrosion resistance. The shielding properties of the Sample 1 and carbon mesh recommend them as potential candidates in the field of protective clothing, EMI gaskets, canopies, and shielding enclosures.

### Acknowledgement

The work has been funded by the Sectoral Operational Programme Human Resources Development 2007-2013 of the Ministry of European Funds through the Financial Agreement POSDRU/159/1.5/S/132397.

### R E F E R E N C E S

- [1] *Gabriel Oprisan, N. Tăranu, Vlad Munteanu and Ioana Ențuc*, “Application of Modern Polymeric Composite Materials in Industrial Construction”, *Bul. Inst. Polit. Iași*, tom. LVI (LX), fasc. 3, 2010, pp. 121-130.
- [2] *Francesco de Paulis, Muhammet Hilmi Nisanci, Antonio Orlandi, Marina Y. Koledintseva, James L. Drewniak*, “Design of Homogeneous and Composite Materials From Shielding Effectiveness Specifications”, *IEEE Transactions on Electromagnetic Compatibility*, vol. 56, no. 2, April 2014; pp. 343-351.
- [3] *M. S. Mirotnik, S. Yarlagadda, R. McCauley, and P. Pa*, “Broadband electromagnetic modeling of woven fabric composites,” *IEEE Trans. Microw. Theory Tech.*, vol. 60, no. 1, Jan. 2012, pp. 158–169.
- [4] *T.-C. Chou, M.-H. Tsai, and C.-Y. Chen*, “A low insertion loss and high selectivity UWB bandpass filter using composite right/left-handed material,” *Progr. Electromagn. Res. C*, vol. 17, 2010, pp. 163–172.
- [5] *M. De Rosa, R. Mancinelli, F. Sarasini, M. S. Sarto, and A. Tamburrano*, “Electromagnetic design and realization of innovative fiber-reinforced broad-band absorbing screens,” *IEEE Trans. Electromagn. Compat.*, vol. 51, no. 3, Aug. 2009, pp. 700–707.
- [6] *Bao Yong-fang, Lu Ying-hua, Zhang Hong-xin, Han Chun-yuan*, “The Analysis of Shielding Effectiveness of Negative Permittivity Composite Materials to Different EMP”, *Proc. IEEE International Symposium on Microwave, Antenna, Propagation and EMC Technologies for Wireless Communications*, vol. 1, Aug. 2005, pp. 635-638.
- [7] *D. R. White*, “Electromagnetic shielding materials and performance”, *Don White Consultants Inc.*, 1980.
- [8] *Jason M. Keith, Nicholas B. Janda, Julia A. King, Warren F. Perger, Troy J. Oxby*, “Shielding Effectiveness Density Theory for Carbon Fiber/Nylon 6,6 Composites”, *Polymer Composites*, vol. 26, Issue 5, October 2005, pp. 671-678.
- [9] *Xiaohuan Wang*, “Investigation of Electromagnetic Shielding Effectiveness of Nanostructural Carbon Black/ABS Composites”, *Journal of Electromagnetic Analysis and Applications*, vol. 3, 2011, pp. 160-164.
- [10] *M. A. Aegerter*, “Sol-Gel Technologies for Glass Producers and Users”, *Kluwer Academic Pub.*, Jun. 2004.
- [11] *C. Morari, I. Balan, J. Pintea, E. Chitanu, I. Iordache*, “Electrical conductivity and electromagnetic shielding effectiveness of silicone rubber filled with ferrite and graphite powders”, *Progress In Electromag. Research M.*, 2011, vol. 21, pp. 93-104.