Shields of Electromagnetic Wave Based on Amorphous and Nanocrystalline Soft Magnetic Materials

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***Abstract*- The paper presents results of measurement of electromagnetic wave shielding effectiveness by shields based on $Fe_{73,5}Cu_1Nb_3Si_{13,5}B_9$ soft magnetic material in nanocrystalline and amorphous form. Manufactured shields were characterised by good elastic properties. The research was carried out in frequency band of 300 MHz – 1 GHz. The highest shielding effectiveness was obtained for sample made of amorphous tape - at frequency of 700 MHz it equals 42 dB.**

I. Introduction

Present economic development causes considerable electromagnetic (EM) radiation emission growth. The source of this emission are not only TV/radio stations, radar systems but also different kinds of technical devices [1, 2]. Intensive growth of demand for electric energy, its transmission and development of electronic, telecommunication and information technology result in significant increase of electromagnetic distortion in human environment. In their everyday life people incessantly meet with a lot of devices such as microwave ovens, screens, inductive heaters, alarms, mobile phones etc. which emit electromagnetic radiation. The cables supplying electric energy for receivers as well as wires used for information transfer are also sources of EM radiation.

To minimize the effect of electromagnetic radiation on living organisms usually various types of shields are used. An electromagnetic radiation shield limits the flow of electromagnetic field between two locations (one with EM field and the other without it), by separating them with a barrier made of material with specified electric and magnetic properties. Typically it is applied to enclosures, separating electrical devices from the 'outside world', and to cables, separating wires from the environment the cable runs through. The application of shields with proper electric conductivity σ, permittivity ε, magnetic permeability μ and appropriate thickness ensures harmonic coexistence of electromagnetic environment with systems and devices which are the part of this environment [3, 4, 5].

In Electrical Institute Division in Wroclaw research work is carried out concerning new composite materials designed for EM shields. The investigation, among others, is focused on developing of magnetic filler for warp in form of nanocrystalline and amorphous materials. High-tech nano- and micro- fillers added to polymer warp due to their shielding, elasticity and easy forming properties can be applied for cables and wires shielding or as kits protected from EM radiation.

materials

In the experiment the amorphous soft magnetic tape of $Fe_{73,5}Cu_1Nb_3Si_{13,5}B_9$ was used for preparation of electromagnetic radiation shields. A part of this tape underwent thermal treatment at temperature of 510 °C in argon atmosphere to obtain magnetic nanocrystallites of - α-Fe(Si) embedded in amorphous matrix. Magnetic properties and shielding effectiveness were examined for both amorphous and nanocrystalline tapes. Magnetic measurements at frequency of 50 Hz were performed by means of computerized measuring system MAG-RJJ-3.0.

Figures 1 – 2 present the hysteresis loops and total specific loss of examined materials.

Test results indicate that nanocrystalline tape is characterized by lower coercivity ($H_c < 1$ A/m) and total specific loss than its amorphous precursor. Crystallization process resulted also in a growth of magnetic permeability and saturation induction of material. Saturation induction of amorphous tape amounts of 0.6 T whereas this value for nanocrystalline tape amounts to about 1.2 T. Initial permeability of examined tape after thermal treatment increased by about 5 times and reached $\mu_i \approx 100\,000$.

II. Experiment

The EM shields based on amorphous material were prepared in form of a tape with thickness of 20 μm and width of 10 mm glued onto thin sheet of paper. The tape strips were arranged in such way to eliminate the gaps between the adjacent strips.

Nanocrystalline tape due to its high brittleness can not be applied in form of tape strips. Therefore it was pulverized. The particle size after milling was lower than 80 μm. For reference purpose the amorphous tape was also milled. Final powders dispersed in resin was spread onto textile material and paper sheet. Its mass density on surface amounted to 12 mg/cm^2. The sample with addition of carbon fibers dispersed in the same type of resin as in case of basing powder was also manufactured. The shields obtained in such way were characterized by good elastic properties.

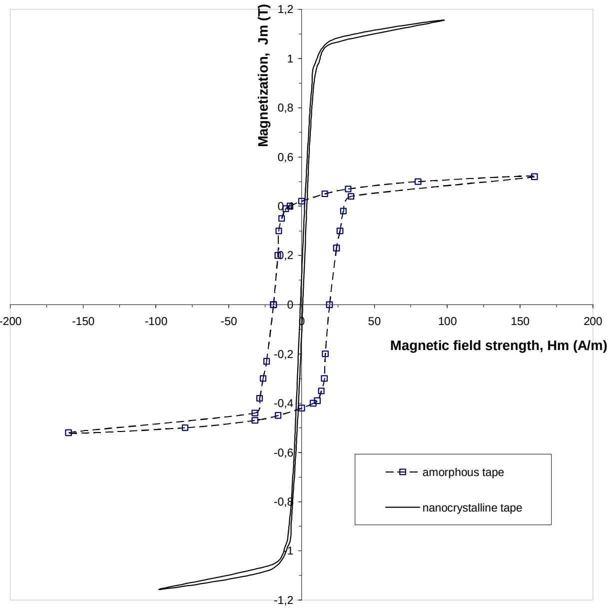

Fig. 1. Hysteresis loop of $Fe_{73,5}Cu_1Nb_3Si_{13,5}B_9$ alloy in amorphous and nanocrystalline form

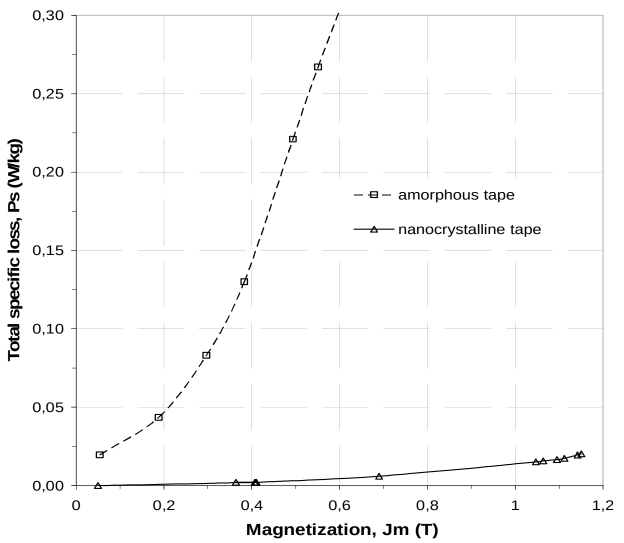

Fig. 2. Total specific loss of $Fe_{73,5}Cu_1Nb_3Si_{13,5}B_9$ alloy in amorphous and nanocrystalline form (f = 50 Hz)

Shielding effectiveness of examined materials was measured according to MIL-STD 285 American standard [6]. Transmitting and receiving antenna were situated at a distance of 3 m from each other in shielded room. Receiving antenna with wooden support was placed in brass housing which was padded inside of ferrite layer. A sample was fixed in opening cut in one of housing side. At first a background measurement (without the sample) was made. In next step, the examined samples were placed in housing and their shielding effectiveness was tested. For shields based on amorphous tape the tests were conducted for samples with and without thin layer of copper foil (0.1 mm and 0.2 mm). The research was carried out in frequency band of 300 MHz – 1 GHz.

III. Results

Shielding effectiveness of manufactured shields are presented in Figs. 3 – 6. The influence of form of applied soft magnetic material (tape or powder) on shielding effectiveness is noticeable.

When it comes to shield made of amorphous tape glued onto sheet of paper the electromagnetic wave shielding changed in range of 9 dB - 42 dB. The highest one (>40 dB) was noted at frequency 710 MHz - 740 MHz. Further increase of frequency resulted in decrease of shielding to 25 dB. In the range of 800 MHz – 1000 MHz shielding effectiveness did not significantly change and amounted about 25 – 30 dB. It should be noticed that samples' thickness was 0,1 mm. Addition of thin copper foil did not have a significant effect on shielding effectiveness results. It indicates that thickness of copper foil is not sufficient to shield an electromagnetic wave effectively.

Pulverization of amorphous material caused deterioration of its shielding properties. In this case the shielding effectiveness is almost constant and does not exceed 10 dB. At frequency of 800 MHz and higher it even dropped below 5 dB. Similar results were also obtained for milled nanocrystalline tape. The addition of carbon fibers to nanocrystalline powder brought about negligible changes in shielding effectiveness.

Shielding effectiveness of specimens made on the basis of milled nanocrystalline and amorphous soft magnetic materials is comparable despite the high difference in magnetic permeability value of blank materials. It might suggest that the size of particles was not properly matched to frequency band. Apart from that, the weaker shielding properties of these samples result from the worse magnetic properties of pulverized materials. Internal stress induced during milling process significantly influenced the magnetic permeability reduction. Additionally non uniform covering of surface by soft magnetic powder also affects samples shielding effectiveness.

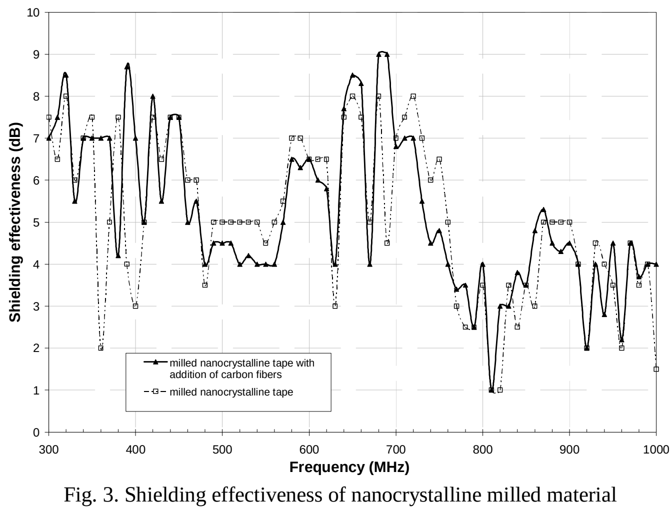

Fig. 3. Shielding effectiveness of nanocrystalline milled material

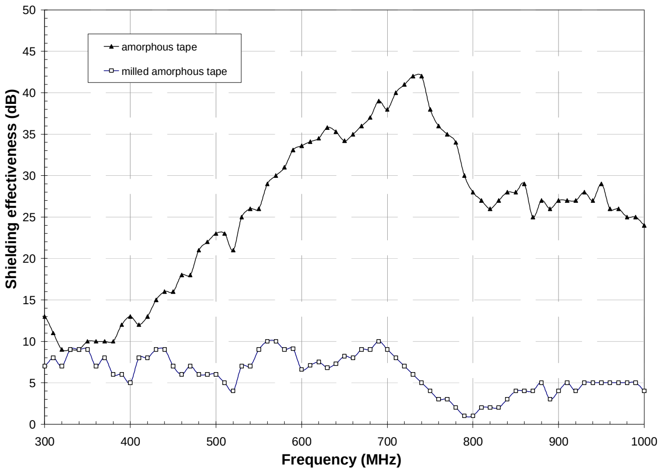

Fig. 4. Shielding effectiveness of amorphous material in tape and powder form

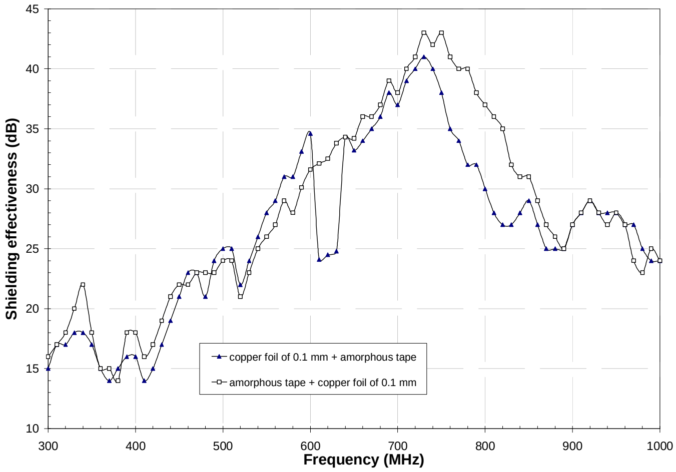

Fig. 5. Shielding effectiveness of amorphous tape with copper foil with thickness 0.1 mm

IV. SUMMARY

The paper presents results of measurement of electromagnetic wave shielding effectiveness by shields based on nanocrystalline and amorphous soft magnetic materials. The research was pilot study with the object of examination of prospects and usefulness of mentioned above materials as the fillers of composite electromagnetic wave shields. That is why the research was concentrated only on "pure" soft magnetic materials (or with small addition of carbon fibers) without composite substrates.

Shielding effectiveness of samples made of soft magnetic amorphous tape is high what indicates that material in such form is proper for usage on EM shields

The obtained results of shielding effectiveness in case of specimens based on pulverized materials are not satisfactory. These kind of shields require amelioration of preparation technology and further tests.

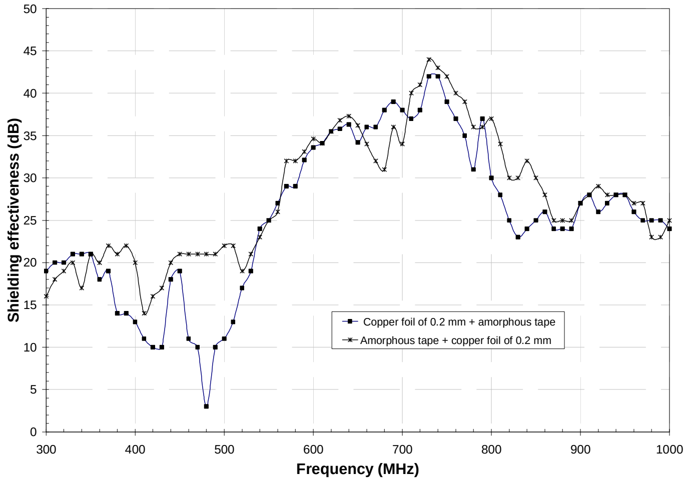

Fig. 6. Shielding effectiveness of amorphous tape with copper foil with thickness 0.2 mm

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