Alexander PROUDNIK[1], Yaugeni ZAMASTOTSKY[2], Viacheslau SIARHEYEV[2], Vsevolod SIUBOROV[2], Elena STANKEVICH[3], Igor POBOL[3]

Belarusian State University of Informatics and Radioectronics (1), Vitebsk State Technological University (2), Scientific and Engineering Centre "Plasmoteg" of the Physical-Technical Institute of the National Academy of Sciences (3)

Shielding properties of the metal coatings deposited by cathodic arc deposition on textile materials

***Abstract**: The aim of work was to develop flexible shielding materials with radio protective properties. The article describes the investigation of the effect of metal coatings and their deposition parameters on the shielding properties of textile materials for creation of materials for protection of human organisms from electromagnetic radiation. The samples were prepared using samples of fabrics and knitted fabrics made from natural, synthetic and artificial fibers and yarns of different weaves. Metal coatings were deposited on the textile materials using arc physical vacuum deposition process (cathodic arc deposition). To create shielding metal coatings Cu, Ti and Cr coatings were used in the coating system. Cu and Ti coatings were created in the vacuum and in the presence of carbon dioxide. Frequency behaviour of electromagnetic radiation attenuation and reflection of the samples in the band of 8...12 GHz was studied using network analyzer and waveguide measurement path. The electromagnetic radiation attenuation provided by the samples of different groups is in the range of 5÷10 dB (21–26.5 dB in the case of use of special carbon fabric) and the reflection characteristics vary in the range of –3÷–11.5 dB depending on the matrix surface shape.*

Keywords: Electromagnetic radiation, flexible shielding materials, cathodic arc deposition, metal coatings, attenuation and reflection characteristics.

Introduction

Shielding materials are applicable wherever exists a necessity to protect against the propagation of the electromagnetic field. The impact of electromagnetic radiation of different nature to the technical and biological objects is a significant factor in their functioning. In recent years, the exponential growth of the quantity of different electromagnetic radiation sources and created by them problems of healthcare demand development of new designs of electromagnetic radiation shields and absorbers.

The development of methods for electromagnetic radiation shielding is very important in the sphere of information security where they are used to suppress the electromagnetic information leakage and in the sphere of protection information processing devices from electromagnetic exposure. A separate trend is the use of such materials to reduce the visibility of military facilities and to improve their noise immunity. To date, such materials are in demand and the demand for them will increase steadily in the near future. This is due primarily to the growing number of sources of electromagnetic radiation and increasing use of different frequency bands. Particularly relevant issue is the suppression of unwanted electromagnetic radiation arising from the imperfection of structures emitting units that have the greatest impact on the human organism [1].

Currently, there is a need for low-cost radar shielding and reflective materials that can be used to make protective shields from various electronic devices. The most actual problem is to produce flexible, air-penetrable, practically feasible and cheap materials to ensure a sufficient degree of suppression of electromagnetic radiation over a wide frequency band. Particular attention is paid to the development of shields, whose effectiveness is achieved through the absorption of electromagnetic radiation.

The materials on the basis of textiles with thin film coatings with proper shielding properties in a wide range of frequencies look perspective if they are characterized by a high level of protection from the effects of external electromagnetic fields, biological compatibility with human organisms and biostability of microorganisms [2].

The aim of this work is to develop flexible materials with shielding properties and to study their attenuation and reflection characteristics.

Experiment

This goal can be achieved by the development of lightweight, thin, flexible, and radar absorbing material having a high coefficient of absorption of electromagnetic radiation, as well as a simple, low-cost method of its manufacture.

The choice of textile materials as substrates for deposition of metals due to their thinness, lightness, flexibility, and are widely used because of the high efficiency of screening and technology applications. The simplest method of manufacture of flexible electromagnetic shields is to apply to textile fabrics metals with high conductivity and shielding efficiency.

The experimental samples were prepared using fabrics and knitted fabrics made from natural, synthetic and artificial fibers and yarns of different weaves. Properties of textile materials are given in the Table 1.

Table 1. Properties of textile materials

Fabric	Weight of fabrics [g/m^2]	linear mass density of fibers [tex]
Viscose	95.1	–
Polyamide	426.1	93.5
Polyester cotton blend (50-50%)	254.9	254.9
Polyester	62.5	7.6
Organza	22	3.3
Linen	390	136

To form the metal coating has been chosen the method of cathodic arc deposition. This is due to the ability to control precisely the parameters of technological processes and their full automation. Second, the low temperature process can handle almost any textile materials (including synthetic) and a high adhesion value of coatings to the substrate can be achieved. Adhesion to the substrate (textile material) of metal layers in cathodic arc deposition, significantly higher than the same coatings obtained by vacuum thermal evaporation at comparable rates of deposition, due to the higher energy of condensing particles. The high density of active nucleation sites leads to the fact that the structure of coatings obtained by these methods is characterized by small grain size for high density packaging. Unlike other methods of metallization, the method of cathodic arc deposition allows to adjust the thickness of the metal layer and hence its resistance, which is very important to create materials with specific conductivity. The method allows regulating the thickness of deposited metal in the range from a few micrometers to several hundred micrometers, and modifying the surface resistivity from several tens to fractions of an Ohm.

The method of cathodic arc deposition is characterized sufficiently by high efficiency and has a number of advantages, basic of them are inertialess process, the ability to obtain uniform coating thickness, good adhesion of coatings to the substrate, an insignificant contamination by extraneous cover gas inclusions, low temperature heating of substrates, obtaining nanostructured films. In the cathodic arc deposition is possible to control the composition of coatings, using multiple cathodes or a multi-cathode. The method is safe for the environment.

Metal coatings were deposited on the textile materials using arc cathodic arc deposition. For deposition of metal coatings was used coating system with stationary and pulsed plasma accelerators. The schematic diagram of the cathodic arc deposition system is shown in Fig. 1.

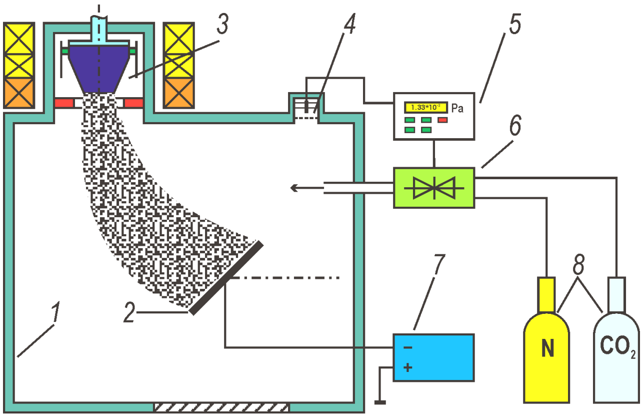

Figure 1. Schematic diagram of the cathodic arc deposition system: *1* — substrate; *2* — vacuum chamber; *3* — the source of metal plasma; *4* — vacuum gauge; *5* — vacuum meter; *6* — gas inlet system; *7* — source of reference voltage; *8* — gas cylinders

To create shielding metal coatings Cu, Ti and Cr cathode targets, shown in Fig. 2 were used in the coating system. Cu and Ti coatings were created in the vacuum and in the presence of carbon dioxide.

Figure 2. Cathode targets used in the cathodic arc deposition process

Metal coatings had quasi-amorphous atomic or fine-grained polycrystalline structure. Cathodic arc deposition process variables are given in the Table 2.

Table 2. Cathodic arc deposition process variables

Process variable	Value
Residual pressure	$3{\cdot}10^{-3}$ Pa
Reagent gas	CO_2 (or vacuum)
Gas pressure	$1{,}5{\cdot}10^{-1}$ Pa
Current on the surface of a cathode	55 A
Deposition time	5–20 min
Coating thickness	0,1–1,5 μm

Results and discussion

Attenuation and reflection characteristics of the samples in the band of 8...12 GHz were measured using network analyzer and waveguide measurement path.

The attenuation and reflection characteristics of the polyamide, linen, polyester and polyester cotton blend coated by the Cu are shown in Fig. 3 and 4 respectively.

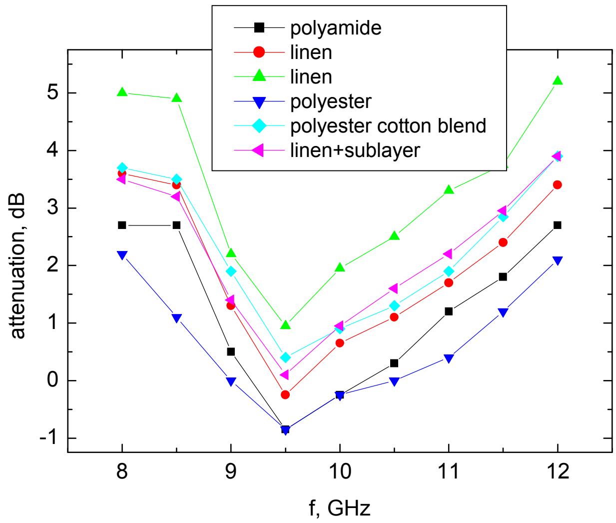

Figure 3. The attenuation properties of the Cu coatings

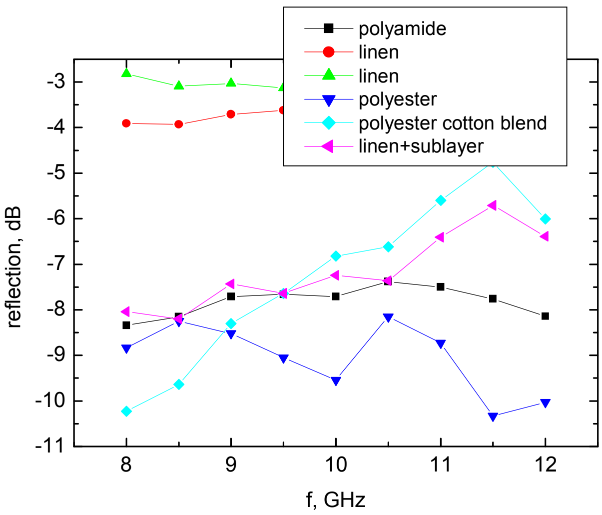

Figure 4. The reflective properties of the Cu coatings

In order to study influence of the carbon presence in the fabric material on the attenuation and reflection characteristics was used the special carbon fabric coated by the Cu. The results are shown in Fig. 5 and 6.

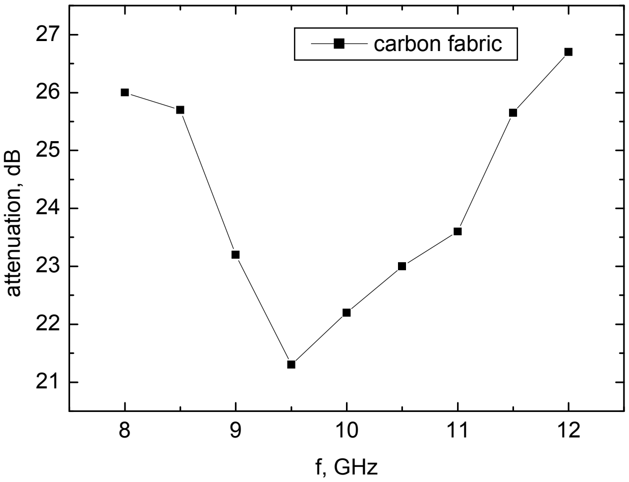

Figure 5. The attenuation properties of the Cu coatings deposited on the carbon fabric

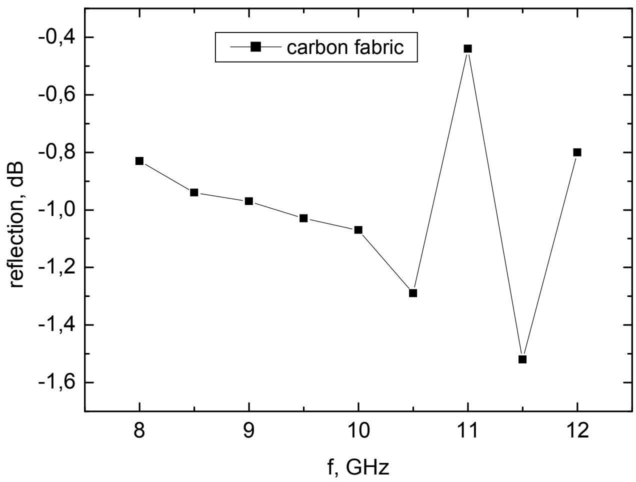

Figure 6. The reflection properties of the Cu coatings deposited on the carbon fabric

The attenuation and reflection characteristics of the polyester, linen, organza, polyester cotton blend and lycra coated by the Ti are shown in Fig. 7 and 8 respectively.

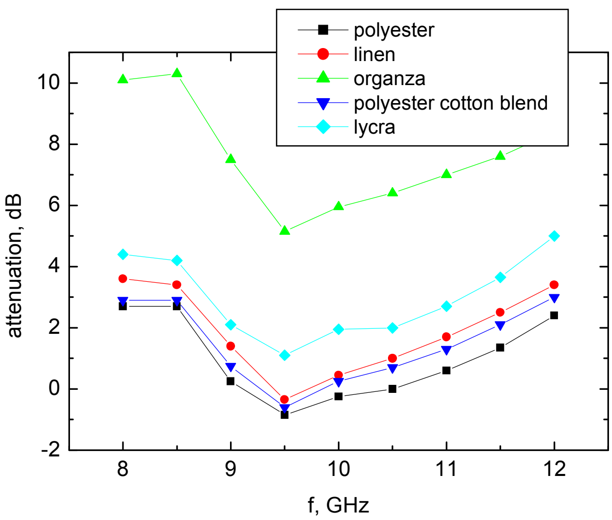

Figure 7. The attenuation properties of the Ti coatings

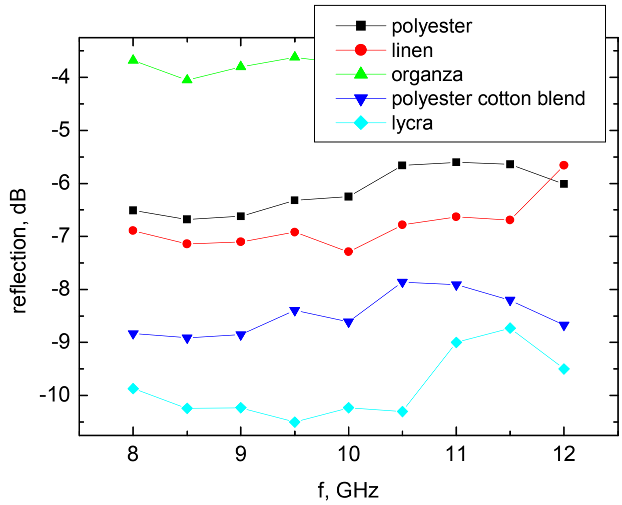

Figure 8. The reflective properties of the Ti coatings

In order to study influence of surface density of the metal coating on the attenuation characteristics was used cardboard coated by the Ti in the vacuum and in the presence of carbon dioxide. The results are shown in Fig. 9.

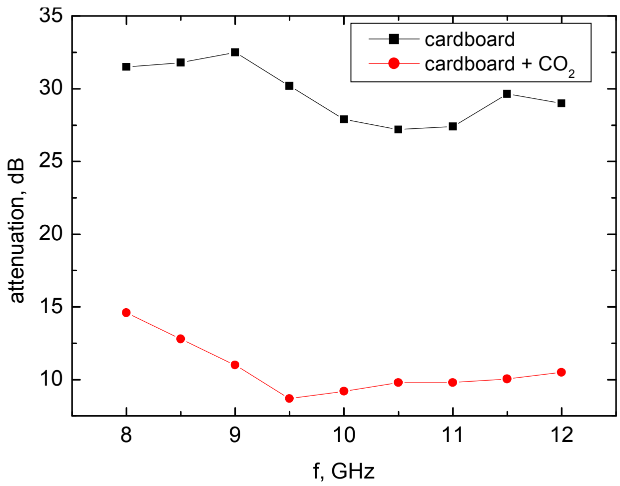

Figure 9. The attenuation characteristics of the cardboard coated by the titanium

The attenuation and reflection characteristics of the polyester cotton blend and heat-resistant fabric "Arselon" coated by the Cr are shown in Fig. 10 and 11 respectively.

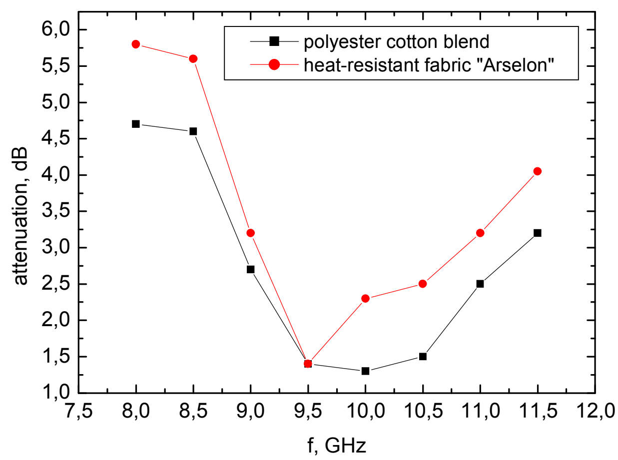

Figure 10. The attenuation properties of the Cr coatings

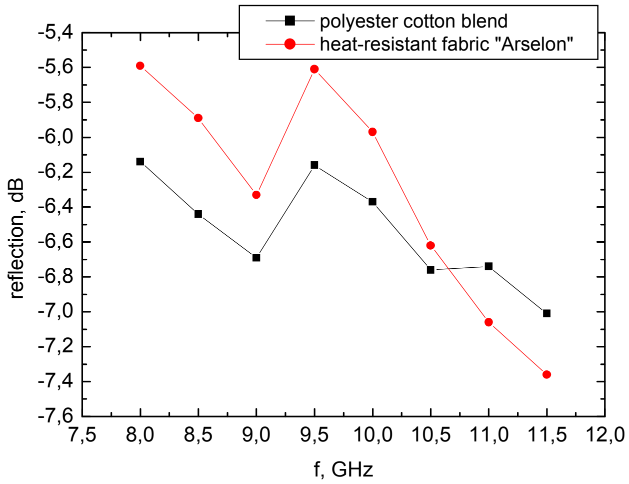

Figure 11. The reflection characteristics of the fabrics coated by the chromium

The electromagnetic radiation attenuation provided by the samples of fabrics coated by the copper is up to 5 dB and the reflection characteristics vary in the range of –3÷–11.5 dB.

The attenuation characteristics provided by the carbon fabric coated by the copper are 21–26.5 dB and the reflection is in the range of –0.4÷–1.6 dB.

The electromagnetic radiation attenuation provided by the samples of fabrics coated by the titanium is up to 10 dB and the reflection characteristics vary in the range of –3.5÷–10.5 dB.

The electromagnetic radiation attenuation provided by the samples of fabrics coated by the chromium is up to 6 dB and the reflection characteristics vary in the range of –5.6÷–7.4 dB.

Conclusions

Studies have shown that the development of the flexible electromagnetic shields and absorbers of electromagnetic radiation based on the metallized textile is perspective and their efficiency in the microwave band (X band).

The main advantages of nanostructured metal coatings based on thin films of copper, titanium and chromium are as follows: the use of one metal coating to obtain textile with high values of the attenuation and reflection characteristics in the frequency band 8–12 GHz, high mechanical strength and heat resistance of the fabrics, non-polluting and non-waste technology for producing.

It can be used to create a light, strong, durable and attractive decorative shielding materials, as well as radar absorbing materials with masking capabilities in microwave band.

References

[1] Kolbun N.V., Borbotko T.V., Kazeka A.A., Proudnik A.M., Lynkou L.M. Simulation of electromagnetic radiation passing through liquid-containing nanostructured materials // 12th International Workshop on Nano-Design Technology and Computer Simulations. Proceedings of SPIE. Vol. 7377, 73770A (2008).

[2] Lynkov L., Proudnik A., Borbotko T., Kolbun N. Wideband electromagnetic shields and absorbers // Korean-Belarusian joint workshop on nanocomposite technology / Daejeon, Korea: The *Korea* Atomic Energy Research Institute (KAERI), April 4–7, 2009. P. 52–86.

Authors*: assoc. prof., Ph.D. Alexander Proudnik, Belarusian State University of Informatics and Radioectronics, P. Brovki Str., 6, Minsk, 220013, BELARUS, E-mail: aleks@bsuir.by; assoc. prof., Ph.D. Yaugeni Zamastotsky, Viacheslau Siarheyev, Vsevolod Siuborov, Vitebsk State Technological University; Moskovsky Prospect, 72, Vitebsk, 210035, BELARUS; Elena Stankevich, dr hab. Igor Pobol, Scientific and Engineering Centre "Plasmoteg" of the Physical-Technical Institute of the National Academy of Sciences, Kuprevich Str., 1, building 3, Minsk, 220141, BELARUS.*