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Electromagnetic response of the three-layer construction on the basis of barium hexaferrite and a foam glass

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Abstract. This paper contains results of study of the frequency dependence of reflection coefficient of the ceramic surface coated with the construction consisting of following layers: metal, composite on the basis of ferrite with hexagonal structure, and foam glass. It is shown that foam glass layer reduces significantly the reflecting characteristics of the construction.

1. Introduction

In the recent years considerable attention is paid to absorbing materials which are widely applied to solve problem of electromagnetic compatibility at production of elements of high-frequency electronics, in the field of equipment of multifunctional screened rooms and defensive industry [1–5]. Given weight and dimensional characteristics, absorbing materials differ on broadbandness, efficiency of interaction with electromagnetic radiation. The main requirements to absorbers along with the maximal absorption of the microwave energy and its minimum reflection are mechanical strength of material, ecological stability and low density, in order to avoid increase of the weight of the protected object.

It is known that magnetic absorbing materials have the least thickness but range of their application is limited to conducting surfaces. However, the problems of protection of dielectric surfaces, for example, of ceramic ones are often met in practice. At the same time change of ceramics structure as result of introduction of additional fillers into structure is undesirable as it can change consumer properties of the product in whole. Such problem can be solved by applying conducting layer on the ceramic surface coated with composite materials on the basis of magnetic material. Carbonyl iron [6, 7] and ferrite with structure of spinel and garnet are the most widely used magnetic material. Unfortunately, the majority of magnetic materials work well in relatively low-frequency range while it is required to widen frequency area up to terahertz. Ferrites with hexagonal structure which have the greatest values of fields of magnetic crystallographic anisotropy, that determines frequencies of natural ferromagnetic resonance, are the most promising materials for application at high frequencies [8, 9]. To ensure efficiency of interaction with electromagnetic radiation it is necessary to match complex wave resistance of coating and air environment. As rule, lamination constructions with decrease of concentration of active phases are used for this purpose. As far as ferrites possess the larger specific weight, total weight of the construction increases. Application of tapered or wedge-like constructions sharply increases coating sizes. These shortcomings can be excluded, using foam glass which is light, long-lived, fireproof material as the matching layer [10, 11]. Variant of multilayer construction consisting of three materials including foam glass, ferrite composite and metalized ceramics is considered in this paper.

The work purpose is to define reflection coefficient of the three layer construction in wide frequency range from 20 to 260 GHz.

2. Raw materials and methods of investigations

The traditional method to obtain foam glass is the powder method based on expansion of foam forming mixture prepared from glass powder with gas forming agent. Use of waste glass as source raw materials solves important ecological problem of utilization of the part of household wastes. Broken glass of the most widespread types of glass such as tare glass and sheet one is the most suitable. Researches on utilization of broken electron-beam tubes, computer monitors and TVs screens are actively carried out, too [12]. One of the main requirements to source raw materials is constancy of chemical composition of glass since deviations from it result in instability of foam glass properties. In this work we have used broken glass presented by sub-standard production of glass-works for manufacturing of LED lamps. Glass has stable composition given in tab. 1 and differs from sheet glass and tare one by presence of barium oxide which is entered into batch by barium sulfate to increase expansion ability of glass melt.

From glass of given composition we have prepared fine ground glass powder with particle size less than 60 μm with addition of carbon-containing gas developing agent in the form of highly active soot with specific surface area of 16 m2/g. According to results of the works which have been carried out early, it has been established that to organize expansion process it is enough 0.5 wt. % of soot. In this experiment soot fulfills the role not only gas developing agent, but also electrically conductive filler which is not completely removed from material at expansion. Combination of porous structure of foam glass with presence of carbonaceous particles provides efficient absorption of electromagnetic wave. Therefore the content of soot in foam forming mixture has been increased up to 1 wt. %.

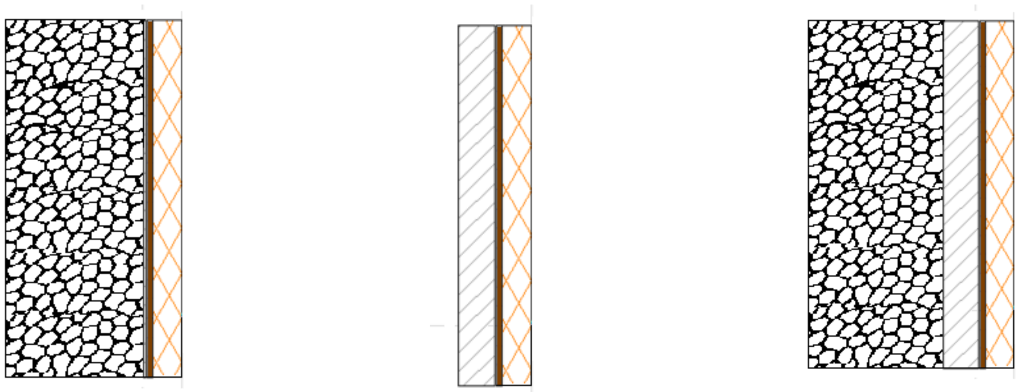
Table 1. The chemical composition of the glass.

Material	Oxides Content, wt. %							
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	BaO
Glass	71,9	0,60	0,10	5,50	3,20	16,10	0,80	1,80
Oxides swing	± 1,5	–	–	± 0,5	± 0,3	± 0,1	± 0,2	± 0,2

The electromagnetic characteristics were investigated using the equipment of the «Center of Radio Measurements at Tomsk State University». Spectra reflection coefficient were measured by the method of free space using a radio spectroscope built around an E8363B Vector Network Analyzer (Agilent Technologies) in the range 20–40 GHz and an STD-21 teraherz spectrometer in the range 115–260 GHz.

3. Experimental results

We have used for measurements the flat samples of ceramics coated with copper foil layer with thickness of 0.5 mm. Reflection coefficient of such construction is practically equal to R= 0 dB – it is the total reflection. Applying of foam glass with thickness of 6.2 mm on this construction (fig. 1.1.) has decreased reflection coefficient almost twice (R= –3 dB) in the range of 20 - 40 GHz (graph.1, fig 2). It is connected with absorbing properties of foam glass which have been revealed earlier. It is connected with absorbing properties of foam glass which have been revealed earlier [11].



1) Foam Glass on Metallized Ceramics   2) Ferrite Composite on Metallized Ceramics   3) Foam Glass + Ferrite Composite on Metallized Ceramics

Figure 1. The principle structure of the investigated multilayered materials.

The curve 2 in the figure 2 corresponds to the construction shown in the figure 1.2 when the layer of magnetic absorber is applied on the metal layer. The absorber represents the composite in which active phase has been presented with ferrite powder of hexagonal structure – $BaFe_{12}O_{19}$ (60 % of total mass), and binding agent has been presented with water dispersion paint. The thickness of composite layer was 1.5 mm. Composite has been polymerized on air in 4 hours. The size of ferrite particles was less than 80 μm. The mixture has been stirred with the "Alena" ultrasonic disperser with action power of 20 W and with frequency of 22 kHz. The reflection coefficient is presented by oscillating function which reflects interference properties of such absorber which are defined with frequency dependences of magnetic and dielectric permittivity and thickness of the particular layer.

On average the reflection coefficient of the sample of ferrite composite on metalized ceramics differs from the coefficient for the sample of foam glass on metalized ceramics a little that is connected with high contrast of complex wave resistance of magnetic coating with free space, while the reflecting properties of foam glass are defined only by the absorbing properties. The reflection coefficient of the construction has been decreased considerably when foam glass layer has been applied on the layer of magnetic composite (fig. 1.3). In low-frequency area reflection has decreased in 10 times and at high frequencies in hundred and more times (graph 3, fig. 2). At that it should be noted the broadbandness of the created construction.

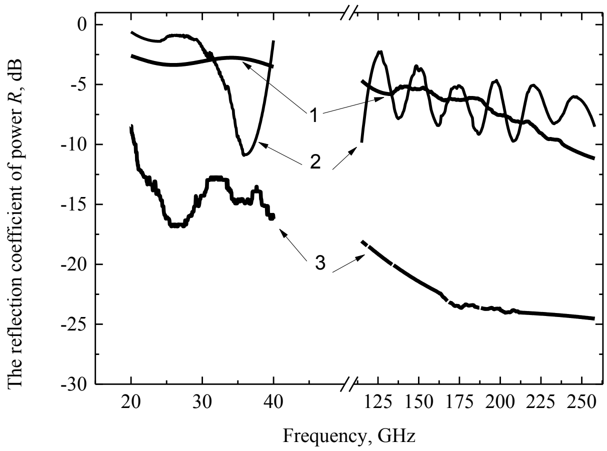


Figure 2. Spectra reflection coefficient of the samples.

4. Conclusions

The conducted research showed that ceramic coatings can be protected from influence of electromagnetic radiation in a wide frequency range using composition: metal, magnetic absorber and foam glass. This construction has relatively small weight, high performance of interaction with microwave, and low weight and dimensional characteristics.

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