Microwave Absorption Properties of Foam Glass Material Modified by Adding Ilmenite Concentrate

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Abstract— Studies of foam glass modified with ilmenite concentrate have demonstrated the improvement of its physicomechanical properties in comparison with foam glass synthesized without additives. This material actively interacts with microwaves and can be used for the development of protective screens reducing the adverse effect of microwaves on biological objects, anechoic chambers, and rooms with low level of electromagnetic background noise. Spectra of the transmission coefficients for frequencies in 26–260 GHz range are presented. The observed effects demonstrate the existence of regions with partial and total reflection arising on the glass-pore boundary and of the microwave interaction with superdispersed concentrate and carbon particles that remain after foaming with incomplete frother transition from the soot to the gas phase.

1. INTRODUCTION

Currently, due to the increasing background microwaves the development of radar absorbing materials (RAM) for various purposes are particularly relevant. RAM are used to solve problems of electromagnetic compatibility of radio electronic devices, protection of biological objects from electromagnetic radiation, as well as to reduce the radar signature objects of military and civil purposes. The materials that combine several useful consumer properties are of particular interest.

The unique combination of properties that do not have any of the known heat insulator has foam glass material. This material is environmentally safe and has a low thermal conductivity and density with relatively high strength. Despite the large number of scientific publications and patents, research in the field of foam glass actively conducted throughout the world [1–6].

In the paper we considers the foam glass obtained through industrial cullet glass tube with the addition of the modifying additive in the form of titanium dioxide from concentrate of ilmenite. Earlier authors have found that small additions of modifying glass foam concentrate material has high strength. When adding the concentrate to the foaming mixture in an amount of 0.5 wt.% compressive strength of the foam glass is doubled.

Selection titanium concentrate on the one hand caused by the fact that TiO_2 is a universal catalyst for the crystallization of the silicate glass. On the other hand, the ilmenite concentrate is ferromagnets. It may affect on the radar-absorbing ability of foam glass.

The purpose of this work — study microwave transmission and reflection coefficients in the frequency range 26–260 GHz of foam glass, modified by titanium concentrates and the establishment of the possibility of its use as a radar absorbing material.

2. PHYSICAL MECHANICAL PROPERTIES OF THE SAMPLES

We used as a raw material for producing foamed glass the powder industrial cullet glass tube with a specific surface area of 6000 cm^2/g. The chemical concentrate composition in wt.% was follow: TiO_2 — 61.85; Fe_20_3 — 27.90; $Si0_2$ — 2.00; $A1_20_3$ — 2.00; CaO — 0.15; MgO — 0.40. Raw powder of TiO_2 was ground in a planetary mill "Pulverisette 6" for 15 and 45 min. The amount of injected concentrate varied from 0.5 to 1.5 wt.%. The effect of additives was assessed by changes in the macrostructure of the samples, density, mechanical strength and electrophysical properties.

Analysis of the particle size of the concentrate composition, carried out by means of the diffraction particle size analyzer SALD-7101 company Shimadzu, showed that the average particles size of concentrate is 3 and 50 microns when activated 15 and 45 minutes respectively. Foaming was conducted for all samples in one mode, with exposure at a maximum temperature of 850°C for 15 minutes using soot 0.5 wt.% as blowing.

Some mechanical properties of these samples are presented in Table 1.

According to the shown in Table 1 results, the introduction of titanium concentrate affects the physical and mechanical properties of foamed glass. With the increasing amount of the admixture

Table 1: Properties of the modified foam glass.

The amount of the concentrate, wt.%	Activation time, min	Average density, kg/m^3	Compressive strength, MPa
0.5	15	133	1.1
	45	115	0.8
1	15	138	1.3
	45	123	0.9
1,5	15	196	2.0
	45	137	1.5
0	–	180	0.9

from 0.5 to 1.5 wt.% increases the average density of the material, regardless of the particle size of the concentrate. The lowest density has activated for 45 minutes samples with a concentrate. Foamed glass materials modified ilmenite concentrate, have relatively high values of strength, low density, which is primarily due to their macrostructure.

3. MICROWAVE PROPERTIES OF THE SAMPLES

Measurements of the electromagnetic waves (EMW) transmission and reflection coefficients were produced by the "free space" method on the two equipments. First built on the basis of a vector network analyzer E8363B of Agilent Technologies in the frequency range 26–36 GHz and second was the terahertz spectrometer STD-21 operating in the frequency range of 60–260 GHz.

For study of the electromagnetic response we used flat samples $3.0 \times 3.0\,cm^2$. Thickness of the samples was 2.2–2.4 cm. The measurements showed that the microwave reflection coefficients for all of the samples are small. This is due to the microwave radar absorptive material properties and diffuse scattering from the surface of foamed glass.

The measurement results are shown in Table 2. With increasing the amount of the ilmenite concentrate that introduced into the foaming mixture the electromagnetic waves transmission coefficients decreases. A minimum value of transmission coefficient has a sample with 1.5 wt.% additive on frequencies 26 GHz and at 260 GHz, as compared with non-modified sample. For non-modified sample the transmission coefficients are −8.9 and −11.2 dB/cm, respectively for frequencies 26 and 260 GHz.

Table 2: Results of measurements of the transmission coefficients of the samples of the modified foam glass.

The amount of the concentrate, wt.%	Activation time, min	Transmission coefficient, dB/cm at a frequencies	
		26 GHz	260 GHz
0.5	15	−10.5	−15.2
	45	−7.7	−8.5
1	15	−8.6	−9.95
	45	−9.3	−10.9
1.5	15	−5.9	−7.3
	45	−7.2	−9.2
0	–	−8.9	−11.2

Uniquely manifested effect of particle size of ilmenite concentrate on the radar absorbing ability foam glass. At low concentrations (0.5 wt.%), a significant reduction (1.5 times) of the transmission coefficients observed in the entire investigated frequency range. While a decrease in particle size from 50 to 3 microns leads to an increase in the transmission coefficient on average 1.2 times.

Referring to Table 1, the best from the standpoint of thermal properties of the foam glass samples is the modified in an amount of 0.5 wt.% ilmenite concentrate samples with a particle size of 3 microns. A sample of that composition has a very high porosity of 95.4% and therefore the lowest density 115 kg/m^3. But it is characterized by the value of the transmission coefficient of 1.25 times lower in comparison with the reference sample without additives.

4. CONCLUSION

The results of this paper showed that the modification of porous glass small additions of ilmenite concentrate can not only improve the properties of the final material, but also to expand its scope. Material is actively interacts with electromagnetic radiation and can be used as an absorber to create: protective shields that reduce the harmful effects of EMW on biological objects; anechoic chambers and rooms with a low level of electromagnetic background.

Optimum properties with position the radar absorbing capacity of the material has samples of foam glass modified additives in 1.5 wt.% ilmenite concentrate with a particle size of 50 microns. The value of the transmission coefficient in this case is reduced to 1.5 times at a frequency of 26 GHz and to 1.32 times at a frequency 260 GHz, compared to the reference sample.

The observed effects can be explained by the existence of areas of partial and total reflection that occur at the interface between the "glass — pore", as well as the interaction of electromagnetic radiation with ultrafine particles of ilmenite concentrate and carbon that remains after foaming with incomplete transition from the soot blowing agent in the gas phase.

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