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Foiled Material and Charcoal BasedCombined Microwave Absorbers with an Orderedly Structured Surface Layer

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Abstract— The paper is related with the problem of development of low-cost technologies for manufacturing microwave absorbers. The paper presents one of such technologies proposed by authors. The absorbers manufactured according to the proposed technologies are multi-layer ones. Their surface (outer) layer is orderedly structured one. It contains the set of 3D-elements made from the foiled material and characterized by one of the following shape: classical Archimedes spiral, loop, Mobius strip. The absorbers intermediate layer contains the particles of the modified activated charcoal. The absorbers inner layer is aluminum foiled polymer base. Paper also presents the results of comparative analysis of 2.0–17.0 GHz frequency responses of electromagnetic radiation absorption coefficient values of the absorbers manufactured according to the proposed technologies depending to the shape of 3D-elements contained on their surface layer. It was established on the base of the comparative analysis results that the absorbers manufactured according to the proposed technologies are characterized by the effective absorption bandwidth 7.5–11.5 GHz which is wider on 0.5–6.0 GHz than effective absorption bandwidth absorbers manufactured only on the base of modified activated charcoal. The absorbers manufactured according to the proposed technologies can be used for the manufacture of the panels for the functional zoning of rooms where electronic devices are located that are sensitive to the effects of microwave radiation and / or are sources of such radiation.

Keywords— charcoal, foiled material, microwave absorber.

I. Introduction

Microwave absorbers are widespread materials nowadays. This is because [1–3]:
– there are many electronic devices which are the sources of microwave radiation;
– microwave radiation could be the interference for the different devices (in privacy, human life support devices,
devices for information processing, monitoring devices etc.);
– some devices for speech information interception are based on use microwave radiation.

So, microwave absorbers are one of the means with use of which it's possible to solve the medical, technical, information security and ecological problems [4–6]. Due to this fact microwave absorbers development and improvement is of the modern scientific scopes. Microwave absorbers development is closely connected with the synthesis new materials reducing the microwave radiation energy by its transforming in the heat. Microwave absorbers improvement is closely connected with their structure modification (adding extra layers, changing the surface shape). The presented paper contains the results of the work targeted on the improvement microwave absorbers based on activated charcoal. Such work was based on the research results presented in the papers [7–10]. According to results presented in the paper [7], microwave absorbers based on activated charcoal impregnated with sodium chloride aqueous solution are characterized by high efficiency and narrower effective absorption bandwidth compared with microwave absorbers based on activated charcoal impregnated with calcium or sodium chloride

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aqueous solution.

The hypothesis about possibility to improve microwave absorbers based on activated charcoal impregnated with sodium chloride aqueous solution and to extend their effective absorption bandwidth was made according to the results presented in the papers [12–14]. The supposed improvement of the marked absorbers within the framework of the hypothesis is based on the adding in their structure surface layer containing the set of 3D-elements made from the foiled material and characterized by one of the following shape: classical Archimedes spiral, loop, Mobius strip.

In general, the aim of the work was to establish the regularities of changes of effective absorption bandwidth of the improved microwave absorbers based on activated charcoal impregnated with sodium chloride aqueous solution depending to the shape of 3D-elements contained on their surface layer.

II. Materials and Methods

A. TheProposedTechnology

Taking into account the proposed hypothesis, three technologies for manufacturing of improved microwave absorbers based on activated charcoal impregnated with magnesium chloride aqueous solution are proposed.

The first of the technologies (hereinafter referred to as Technology 1) includes the following operations.

1. Formation of the first layer of the absorber.

1.1. Cutting off two identical fragments from a roll of synthetic non-woven fibrous material, the length, width and shape of which are determined by the requirements for the length, width and shape of the absorber being manufactured.

1.2. Cutting off identical rectangular fragments from a roll of aluminum foil to form 3D spiral elements.

1.3. Formation of identical 3D spiral elements from aluminum foil fragments obtained as a result of the implementation of operation 1.2, using a stencil plate containing depressions, the shape of which repeats the shape of the classical Archimedes spiral.

1.4. Distribution of 3D spiral elements formed as a result of the implementation of operation 1.3, with a step of 1.0 cm on the surface of one of the fragments of synthetic non-woven fibrous material cut as a result of the implementation of operation 1.1.

1.5. Placing the second of the fragments of synthetic non-woven fibrous material cut as a result of the implementation of operation 1.1, on top of the set of 3D spiral elements made of aluminum foil formed as a result of the implementation of operation 1.4.

1.6. Heat pressing of the structure obtained as a result of the implementation of operations 1.1–1.5.

2. Formation of the second layer of the absorber.

2.1. Cutting two identical fragments from a roll of self-adhesive polymer film, the overall dimensions and shape of which are determined by the requirements for the overall dimensions and shape of the absorber being manufactured.

2.2. Impregnation of powdered activated charcoal with sodium chloride aqueous solution with a concentration of 35.0±1.0%.

2.3. Uniform distribution of a layer of 0.3±0.1 cm thick particles of powdered activated charcoal impregnated with sodium chloride aqueous solution of over the surface of the adhesive layer of one of the fragments of the self- adhesive polymer film opened as a result of implementing operation 2.1.

2.4. Placing the second of the fragments of the self-adhesive polymer film as a result of implementing operation 2.1 opened with the adhesive side on top of the layer of distributed particles of powdered activated charcoal impregnated with sodium chloride aqueous solution, on the fragment obtained as a result of implementing operation 2.3, so that the boundaries of these fragments coincide.

3. Formation of the third layer of the absorber by cutting off a fragment from a roll of aluminum-containing foiled polymer film, the overall dimensions and shape of which are determined by the requirements for the overall dimensions and shape of the absorber.

4. Fastening with spray adhesive to one of the surfaces of the second layer formed as a result of implementing operation 2, the first layer formed as a result of implementing operation 1, and to the other surface of the second layer, the third layer formed as a result of implementing operation 3.

The second of the technologies (hereinafter referred to as Technology 2) includes the following operations.

1. Forming the first layer of the absorber.

1.1. Cutting off fragments from a roll of foiled polymer film taking into account the following conditions:
– the length of each fragment is equal to the length of the absorber being manufactured;
– the width of each fragment is 10.0 cm.

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1.2. Adhesive bonding of two opposite edges of a larger size on each of the fragments obtained as a result of implementing operation 1.1.

1.3. Cutting each of the elements obtained as a result of implementing operations 1.1, 1.2 with a step of 0.9 cm.

1.4. Cutting off a fragment from a roll of radio-transparent polymer film, the overall dimensions and shape of which are determined by the requirements for the overall dimensions and shape of the absorber being manufactured.

1.5. Fastening sets of 3D elements with shape of the loop made of aluminum-containing foiled polymer film obtained as a result of implementing operations 1.3–1.4, on one of the surfaces of the fragment cut as a result of implementing operation 1.4.

2. Forming the second and third layers of the absorber by alternately implementing operations 2 and 3, respectively, of the above-described Technology 1.

3. Implementing operation 4 of the above-described Technology 1.

The third of the technologies (hereinafter referred to as Technology 3) includes the following operations.

1. Forming the first layer of the absorber.

1.1. Cutting identical fragments from a roll of aluminum-containing foiled polymer film to form 3D elements in the form of Mobius strips, taking into account the following conditions:

– the length of each film fragment is 5.0 cm; – the width of each film fragment is 0.5 cm.

1.2. Forming 3D elements with shape of the Mobius strips from fragments of aluminum-containing foiled polymer film cut during the implementation of operation 1.1.

1.3. Cutting off a fragment from a roll of radio-transparent polymer film, the overall dimensions and shape of which are determined by the requirements for the overall dimensions and shape of the absorber being manufactured.

1.4. Fastening, with a step of 1.0 cm, 3D elements with shape of the Mobius strips, formed during the implementation of operation 1, on one of the surfaces of the fragment cut during the implementation of operation 2, taking into account that the said elements must be located at an angle of 45° with respect to the surface of the said fragment.

2. Forming the second and third layers of the absorber by alternately implementing operations 2 and 3, respectively, of the above-described Technology 1.

3. Implementation of operation 4 of the above-described Technology 1.

Thus, the surface layer of the microwave absorbers manufactured according to the Technology 1 contains the set of 3D-elements with shape of the Archimedes spiral (Fig. 1). The surface layer of the microwave absorbers manufactured according to the Technologies 2 and 3 contains the set of 3D-elements with shape of the loop and Mobius strip respectively (Figs. 2, 3).

Fig. 1 Appearance of the 3D-element with shape of the Archimedes spiral

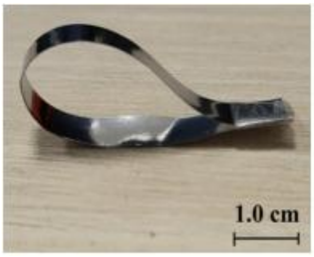

Fig. 2 Appearance of the 3D-element with shape of the loop

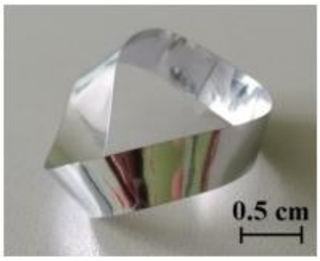

Fig. 3 Appearance of the 3D-element with shape of the Mobius strip

B. TheResearchMethodology

In course of the research the following was done:

1) 4 group of the microwave absorbers experimental samples was manufactured;

2) electromagnetic radiation reflection and transmission coefficients values (R and T respectively) in the

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frequency range 2.0–17.0 GHz of the manufactured samples were measured;

3) electromagnetic radiation absorption coefficient values (A) of the manufactured samples were calculated on the base of the measured Rand T;

4) the comparative analysis of 2.0–17.0 GHz frequency responses of Avalues of the manufactured samples have been performed.

The characteristics of the manufactured microwave absorbers experimental samples are presented in Table 1.

TABLE I
THE CHARACTERISTICS OF THE MANUFACTURED MICROWAVE ABSORBERS EXPERIMENTAL SAMPLES

Sample designation	**Technology used for the sample manufacturing**
Sample of the group 1	Technology 1 (only operations 2–4)
Sample of the group 2	Technology 1
Sample of the group 3	Technology 2
Sample of the group 4	Technology 3

Rand Tvalues of the manufactured samples were measured with use of the panoramic meter of the reflection and transmission coefficients and two horn antennas according to the method presented in the paper [11]. Avalues of the manufactured samples were calculated according to the formulas presented in the marked paper.

III. Results and Discussion

2.0–17.0 GHz frequency responses of A values of the samples of the manufactured microwave absorbers experimental samples are presented in on Fig. 4.

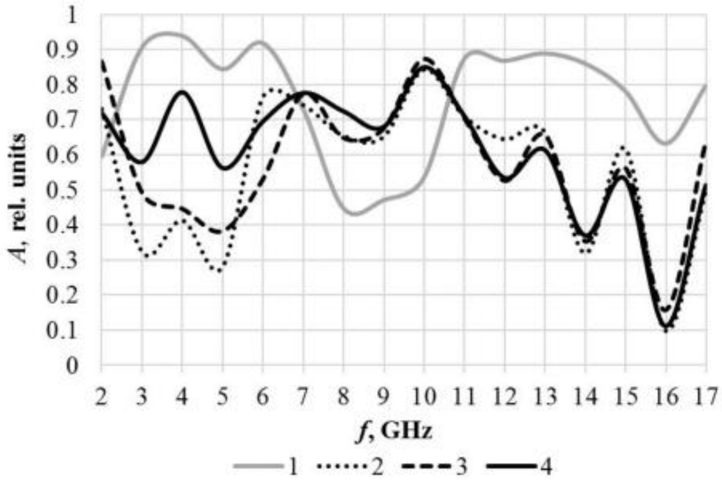

Fig. 4 2.0–17.0 GHz frequency responses of Avalues of the samples of the groups 1, 2, 3 and 4 (curves 1, 2, 3 and 4 respectively)

As it can be seen from Fig. 4, Avalues in the frequency range of 7.0–10.5 GHz of the samples of the groups 2, 3 and 4 exceed by 0.05–0.35 rel. units Avalues in the specified frequency range of the samples of the group 1. This is due to the fact that A values in the frequency range of 7.0–10.5 GHz of the second of the above-mentioned samples exceed by 0.05–0.3 rel. units Avalues in the specified frequency range of the first of the above-mentioned samples (Fig. 5).

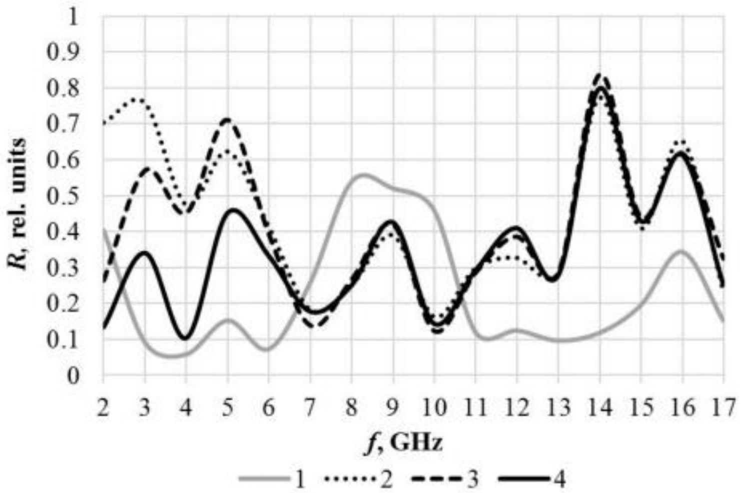

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Fig. 5 2.0–17.0 GHz frequency responses of Rvalues of the samples of the groups 1, 2, 3 and 4 (curves 1, 2, 3 and 4 respectively)

According to the Fig. 4, we concluded that effective absorption bandwidth the samples of the groups 2, 3 and 4 is greater on 0.5–6.0 GHz then effective absorption bandwidth the samples of the group 1 (Table 2).

TABLE II
MANUFACTURED MICROWAVE ABSORBERS EXPERIMENTAL SAMPLES CHARACTERISTICS

The absorber brief description	Effective absorption band range	Effective absorption bandwidth, GHz
Double-layer microwave absorbers based on activated charcoal impregnated with sodium chloride aqueous solution (i. e. microwave absorbers manufactured according to the operations 2–4 of the Technology 1)	2.0–7.5 GHz; 10.0–17.0 GHz	5.5 7.0
Microwave absorbers manufactured according to the Technology 1	2.0–2.5 GHz 5.5–13.5 GHz	0.5 8.0
Microwave absorbers manufactured according to the Technology 2	2.0–3.0 GHz 6.0–13.5 GHz	1.0 7.5
Microwave absorbers manufactured according to the Technology 3	2.0–13.5 GHz	11.5

IV. CONCLUSIONS

Thus, microwave absorbers manufactured according to the proposed technologies are wideband ones. This is because the 3D-elements containing in their surface layers provide microwaves dissipating. These absorbers can be used for the development of the:

– partitions functional zoning of rooms (i.e. allocation of shielded zones in rooms) in which electronic devices are located that are sensitive to the effects of microwave radiation and / or are sources of such radiation;

– modules intended for cladding the walls of shielded rooms in which electronic devices are located that are sensitive to the effects of microwave radiation and / or are sources of such radiation.

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