http://dx.doi.org/10.35596/1729-7648-2022-20-8-28-33

Original paper
Оригинальная статья

UDC 537.874

THE TECHNIQUE FOR MANUFACTURING FLEXIBLE ELECTROMAGNETIC SHIELDS BASED ON RESISTIVE MATERIALS

H. AYAD

University of Zawia (Az-Zawiyah, Libya)

Submitted 28.09.2022

Abstract. The article introduces the technique for manufacturing flexible electromagnetic shields based on resistive materials (powdered charcoals and sheet foil), as well as the results of experimental justification of the use prospects of this technique in the development of new functional materials. This justification consisted of: 1) manufacturing of the experimental samples in accordance with the presented technique; 2) carrying out the measurements of the electromagnetic radiation reflection and transmission coefficient values in the frequency range of 0.7–17.0 GHz of the manufactured experimental samples. It was discovered that flexible electromagnetic shields based on the powdered charcoals manufactured in accordance with the presented technique are characterized by the electromagnetic radiation reflection coefficient values in the frequency range of 0.7–17.0 GHz, reaching –10.0 dB, when electromagnetic radiation reflection coefficient values reach –20.0 dB . Due to this fact it is possible to recommend to use them in order to ensure electromagnetic compatibility of radioelectronic equipment and to protect people from exposure to radiation, emitted by such equipment, as well as to hide ground objects from detection in the radar wavelength range.

Keywords: electromagnetic shield, resistive material, technique.

Conflict of interests. The author declares no conflict of interests.

Acknowledgement. The author is grateful to the Associate Professor of the Information Protection Department of the Belarusian State University of Informatics and Radioelectronics Boiprav O. V. for assistance in measuring the electromagnetic radiation reflection and transmission coefficients values of the samples and for participating in the discussion of the results of these measurements.

For citation. Ayad H. (2022) The Technique for Manufacturing Flexible Electromagnetic Shields Based on Resistive Materials. *Doklady BGUIR.* 20 (8), 28–33. http://dx.doi.org/10.35596/1729-7648-2022-20-8-28-33.

ТЕХНОЛОГИЯ ИЗГОТОВЛЕНИЯ ГИБКИХ ЭЛЕКТРОМАГНИТНЫХ ЭКРАНОВ НА ОСНОВЕ РЕЗИСТИВНЫХ МАТЕРИАЛОВ

Х. АЙАД

Университет Завия (Аз-Завия, Ливия)

Поступила в редакцию 28.09.2022

Аннотация. В статье представлены технология изготовления гибких электромагнитных экранов на основе резистивных материалов (порошкообразного угля и листовой фольги), а также результаты экспериментального обоснования перспектив использования этой технологии при разработке новых функциональных материалов. Это обоснование заключалось в следующем: 1) изготовление экспериментальных образцов согласно представленной технологии; 2) проведение измерений значений коэффициентов отражения и передачи электромагнитного излучения в диапазоне частот 0,7–17,0 ГГц изготовленных экспериментальных образцов. Установлено, что гибкие электромагнитные экраны на основе порошкообразных древесных углей, изготовленные согласно представленной технологии, характеризуются значениями коэффициента отражения электромагнитного излучения в диапазоне частот 0,7–17,0 ГГц, достигающими –10,0 дБ, при значениях коэффициента отражения электромагнитного излучения –20,0 дБ. В связи с этим можно рекомендовать использование таких экранов для обеспечения электромагнитной совместимости радиоэлектронных средств и защиты людей от воздействия излучения, генерируемого такими средствами, а также для скрытия наземных объектов от обнаружения в радиолокационном диапазоне длин волн.

Ключевые слова: электромагнитный экран, резистивный материал, технология.

Конфликт интересов. Автор заявляет об отсутствии конфликта интересов.

Благодарность. Автор выражает благодарность доценту кафедры защиты информации Белорусского государственного университета информатики и радиоэлектроники Бойправ О. В. за помощь в измерении значений коэффициентов отражения и передачи электромагнитного излучения образцов и за участие в обсуждении результатов этих измерений.

Для цитирования. Айад, Х. Технология изготовления гибких электромагнитных экранов на основе резистивных материалов / Х. Айад // Доклады БГУИР. 2022. Т. 20, № 8. С. 28–33. http://dx.doi.org/10.35596/1729-7648-2022-20-8-28-33.

Introduction

Nowadays electromagnetic shields are used to solve the following tasks:

1) hiding objects from detection in the radar wavelength range;
2) ensuring electromagnetic compatibility of radio-electronic equipment;
3) protection of people from exposure to radiation from radioelectronic equipment.

Electromagnetic shields are made on the basis of magnetic and / or resistive materials (that is, materials characterized by high values of magnetic permeability and / or electrical conductivity) [1]. Electromagnetic shields based on magnetic materials are narrow-band. This means that they provide absorption of the energy of electromagnetic radiation in a narrow band of radio frequency range (the difference between the boundary values of this band is 0.5–1.0 GHz) as shown in papers [2–4]. Due to the fact that electromagnetic shields based on magnetic materials are narrow-band, they are suitable, as a rule, to solve of the third task presented above.

Electromagnetic shields based on resistive materials are wide-band compared to radio absorbers based on magnetic materials, which is confirmed by the results of studies presented in the papers [5–7]. That's why they are suitable to solve all tasks presented above. In this regard, the objects of the current research are electromagnetic shields based on resistive materials. The main problems currently being solved in the field of electromagnetic shields improvement are:

– reducing the time spent on the manufacture of radioabsorbers (or increasing the radioabsorbers manufacturability);

– reducing the cost of radioabsorbers based on resistive materials.

The first of the presented problems is due to the fact that most modern electromagnetic shields based on resistive materials are polymer composites obtained by distributing carbon materials (carbon black, carbon nanotubes, carbon fibers or nanofibers, graphene, graphene oxide) in the bulk of a liquid-phase polymer matrix with further molding and drying under standard or specially designed conditions of the resulting material [8]. The second of the presented problems is due to the high cost of carbon materials listed above. In addition, both of the presented problems are due to the fact that the process of manufacturing of electromagnetic shields based on resistive materials is accompanied by the need to use a wetting agent to improve the adhesion of the binder to filler (i. e. resistive material (-s)) particles [9–11].

To solve the above problems in the field of improvement of electromagnetic shields based on resistive materials, nowadays powdered charcoals are proposed for their manufacture [12–14]. The aim of the current work was to develop and experimentally justify new high-manufacturability technique of charcoal-based electromagnetic shields obtaining.

The following tasks have been solved to achieve the aim:

1) the developed technique has been described;

2) the experimental samples have been made according to the developed technique;

3) the measurements of the electromagnetic radiation reflection and transmission coefficients values of the manufactured experimental samples have been carried out in the frequency range 0.7–17.0 GHz;

4) the regularities of changes of the electromagnetic radiation reflection and transmission coefficients values in the frequency range 0.7–17.0 GHz of the manufactured experimental samples have been established and substantiated, depending on the type of charcoal contained in their composition;

5) the recommendations for the practical application of radioabsorbers manufactured in accordance with the developed technique have been proposed.

Materials and methods

The developed technique for radioabsorbers obtaining on the base of the listed resistive materials includes the following stages:

– preparation of rectangular canvases of polyurethane foam (Fig. 1) – the size and shape of such canvases should correspond to the requirements to the developed radioabsorbers;

– preparation of rectangular canvases from the mesh made of polyethylene (Fig. 1) – the size and shape of such canvases should correspond to the requirements to the developed radioabsorbers;

– preparation of rectangular canvases from the polyethylene film with a thickness of 10 microns – the size and shape of such canvases should correspond to the requirements to the developed radioabsorbers;

– arrangement the canvas based on a polyethylene mesh on top of the canvas based on polyurethane foam (Fig. 1, *a*);

– obtaining powdered charcoal: grinding pieces of charcoal to powder with a particle size of up to 200 μm;

– preparation of alkaline earth chlorides aqueous solutions at equilibrium concentration;

– mixing the obtained powdered charcoal with the prepared aqueous solutions in a volumetric ratio of 2:1 (Fig. 1, *b*);

– application of the resulting mixture with a layer of (3.0 ± 1.0) mm thick on the surface of canvases based on polyurethane foam and polyethylene mesh;

– arrangement of the canvas based on a polyethylene mesh over the applied mixture;

Fig. 1. Illustrations of the results of the developed technique main stages implementation

– arrangement of the canvas based on polyurethane foam on top of a polyethylene mesh cloth;

– sealing the resulting structure by placing it between rectangular canvases based on a polyethylene film with a thickness of 10 μm and further joining along the perimeter of these canvases using the soldering method (Fig. 1, *c*).

In comparison with analogs, the developed technique is characterized by such advantage as reduced time costs for implementation, which is due to the following features:

1) the absence of the stage associated with the creation of conditions for drying the binder, due to the fact that the retention of powdered charcoal particles in the volume of radioabsorbers manufactured in accordance with the developed technique is ensured not by the binder, but by the mesh and polyurethane foam (i.e. the use of binders is not provided within the framework of the manufacturing process of radioabsorbers in accordance with the developed technique);

2) the absence of the stage associated with the use of wetting agents.

In accordance with the developed technique, three groups of experimental samples of radio absorbers have been made, differing in the type of charcoal contained in their composition. Tabl. 1 provides information on these samples.

Measurements of the electromagnetic radiation reflection and transmission coefficients values of the manufactured samples have been performed in the frequency range 0.7–17.0 GHz using a scalar network analyzer. The measurements have been carried out in the specified frequency range due to the fact that most of the modern transmitting and receiving equipment operates in it, and also due to the fact that unwanted emissions of modern radioelectronic equipment are characterized by frequencies whose values belong to the specified range [15].

Results and discussion

Fig. 2 shows the frequency dependences of the electromagnetic radiation reflection coefficient in the range of 0.7–17.0 GHz of the manufactured samples.

Table 1. Information about the manufactured experimental samples

Name of the experimental samples group	Type of the charcoal, contained in the experimental samples	Thickness, mm	Weight of 1 m^2, kg	Quality of the experimental samples in the group
Samples of the group 1	Non-activated wood charcoal		1.5 ± 0.05	
Samples of the group 2	Activated wood charcoal	20 ± 1	1.6 ± 0.05	10
Samples of the group 3	Activated coconut charcoal		1.65 ± 0.05	

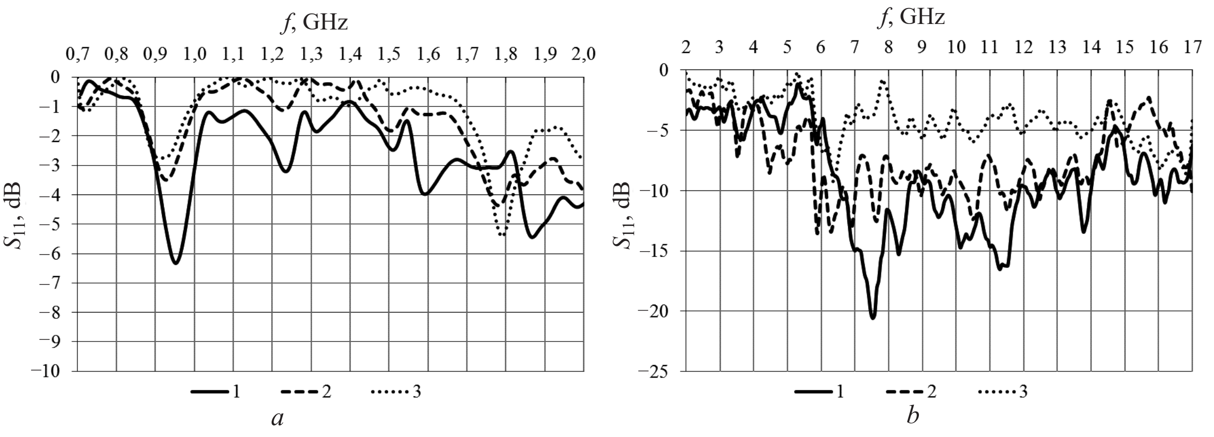

Fig. 2. Frequency dependences of the electromagnetic radiation reflection coefficient in the range of 0.7–2.0 GHz (*a*) and 2.0–17.0 GHz (*b*) of the manufactured samples: 1 – samples of the group 1; 2 – samples of the group 2; 3 – samples of the group 3

It follows from Fig. 2 that the lowest electromagnetic radiation reflection coefficient values in the frequency range 0.7–17.0 GHz are found in samples based on non-activated wood charcoal. These values range from –1.0 to –20.0 dB. Samples based on wood and coconut activated charcoals in the frequency range 0.7–2.0 GHz are characterized by the electromagnetic radiation reflection coefficient values ranging from –0.5 to –6.0 dB. In the frequency range 2.0–17.0 GHz, the values of the considered parameter for such samples, respectively, vary in the range from –2.0 to –15.0 dB and from –2.0 to –8.0 dB.

Lower values of the electromagnetic radiation reflection coefficient in the frequency range 0.7–17.0 GHz of the samples based on non-activated wood charcoal compared to samples based on activated wood and coconut charcoals are due to the following features:

1) the value of the reflection loss of electromagnetic radiation, provided by the material, is directly proportional to the value of its specific electrical conductivity [15];

2) it was experimentally established that the value of the specific electrical conductivity of a mixture of unactivated wood charcoal and $CaCl_2$ aqueous solution is 9 S/m and below the values of the specific electrical conductivity of the mixture of activated wood charcoal and $CaCl_2$ aqueous solution (25 S/m) and the mixture of activated coconut charcoal and $CaCl_2$ aqueous solution (75 S/m) [13].

Fig. 3 shows the frequency dependences of the electromagnetic radiation transmission coefficient in the range of 0.7–17.0 GHz of the manufactured samples.

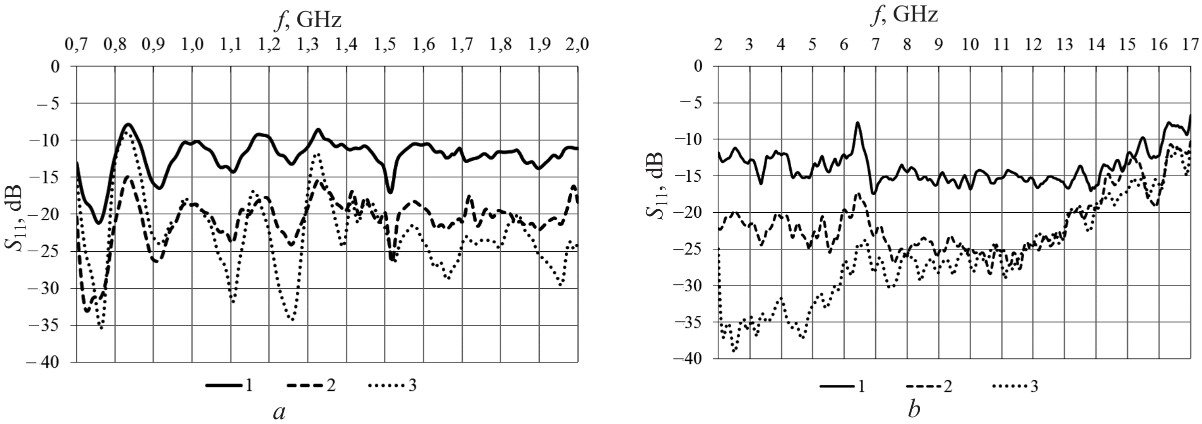

Fig. 3. Frequency dependences of the electromagnetic radiation transmission coefficient in the range of 0.7–2.0 GHz (*a*) and 2.0–17.0 GHz (*b*) of the manufactured samples: 1 – samples of the group 1; 2 – samples of the group 2; 3 – samples of the group 3

It follows from Fig. 3 that the electromagnetic radiation transmission coefficient coefficient values in the frequency range 0.7–17.0 GHz of the manufactured samples vary within the following limits:

1) from –10.0 to –15.0 dB – for the samples based on non-activated wood charcoal;

2) from –20.0 to –25.0 dB – for the samples based on activated wood charcoal;

3) from –25.0 to –35.0 dB – for the samples based on activated coconut charcoal.

Experimental samples based on activated coconut charcoal are characterized by lower values of the electromagnetic radiation transmission coefficient in comparison with other experimental samples due to the fact that a mixture of activated coconut charcoal and $CaCl_2$ aqueous solution is characterized, as indicated above, by high values of the specific electrical conductivity compared to the mixture of non-activated wood charcoal and $CaCl_2$ aqueous solution and to the mixture of activated wood charcoal and $CaCl_2$ aqueous solution.

Conclusion

Based on the results of studying the samples of electromagnetic shields manufactured in accordance with the developed technique, the following conclusions can be drawn.

1. Electromagnetic shields based on activated coconut charcoal seem to be promising for use in the manufacture of partitions intended for placement between units of radioelectronic equipment, as well as workwear for people serving radio electronic equipment, which is a source of high-intensity electromagnetic radiation. This recommendation is due to the fact that these shields are characterized by low values of the electromagnetic radiation transmission coefficient (up to –40.0 dB) in the frequency range 0.7–17.0 GHz.

2. Electromagnetic shields based on wood charcoal (non-activated and activated) are promising for use in the manufacture of structures designed to hide ground objects from detection in the radar wavelength range. This recommendation is due to the fact that these shields are characterized by low values of the electromagnetic radiation reflection coefficient (from –10.0 till –20.0 dB) in the X-frequency range.

References

1. Saville P. (2005) *Review of Radar Absorbing Materials*. Canada.
2. Adi W. A., Yunasfi Y., Mashadi M., Winatapura D. S., Mulyawan A., Sarwanto Y., Gunanto Y. E., Taryana Y. (2019) Metamaterial, In. *Electromagnetic Fields and Waves*. UK, IntechOpen Publ.
3. Fisli D. S., Winatapura E., Sukirman S., Mustofa W. A. A., Taryana Y. (2019) Iron Oxide/Titania Composites for Radar Absorbing Material (RAM) Applications. *Cerâmica*. 65 (375), 470–476. DOI: 10.1590/0366-69132019653752728.
4. Maltsev A. A., Bibikov S. B., Maltseva I. E., Marnautov N. A., Komissarova L. Kh., Elfimov A. B. (2020) Working out the Method of Obtaining Radio-Absorbing Composite Material Based on Magnetite Nanoparticles and Polydimethylsiloxanes. *Key Engineering Materials*. 869, 362–366. DOI: 10.4028/www.scientific.net/KEM.869.362.
5. Ban G., Liu Z., Ye S., Yang H., Tao R., Luo P. (2017) Microwave Absorption Properties of Carbon Fiber Radar Absorbing Coatings Prepared by Water-Based Technologies. *RSC Advances*. 26658–26664.
6. Delfini M. A., Vricella A., Santoni F., Rubini G., Pastore R., Marchetti M. (2018) Advanced Radar Absorbing Ceramic-Based Materials for Multifunctional Applications in Space Environment. *Materials (Basel).* 11 (9), 1730. DOI: 10.3390/ma11091730.
7. Ney Boss A. F., Ferreira H. R., Braghiroli F. L., Amaral-Labat G. A. , Teixeira de Souza A. A., Bouafif H., Koubaa A., Baldan M. R., Lenz e Silva G. F. B. (2021) Investigation of Sustainable Porous Carbon as Radar Absorbing Material. *Materia (Rio de Janeiro).* 26 (2). DOI: 10.1590/S1517-707620210002.1263.
8. Setua D. K., Mordina B., Srivastava A. K., Roy D., Prasad N. E. (2020) Carbon Nanofibers-Reinforced Polymer Nanocomposites as Efficient Microwave Absorber In. *Fiber-Reinforced Nanocomposites: Fundamentals and Applications*. Elsevier Publ.
9. Dong Shijin, Bai Anyang, Wang Hongzhang, Yu Yang Liu Jing (2019) Electromagnetic Shielding Coating Material and Preparation Method Therefor. Patent WO2019033834A1. Publ. 21.02.2019.
10. Zeng Jun, Jiang Xiaoyun, Jiang Yishang, Chen Zhonggang, Liu Qinghua, Tang Junyi (2020) Halogen-Free Flame-Retardant Electromagnetic Shielding Material and Preparation Method and Application Thereof. Patent CN108003771B. Publ. 22.05.2020.
11. Yu Zhengping, Zhang Tao, Shi Xiaobo, Wang Yong, Zhang Hongchuan, Zhang Guangbin, Wang Yuan (2012) Composite Coating Electromagnetic Shielding Paint and Composite Coating Electromagnetic Shielding Material Prepared Therefrom. Patent CN102020899B. Publ. 30.05.2012.
12. Lynkou L. M., Bogush V. A., Borbot'ko T. V., Nasonova N. V., Belousova E. S., Boiprav O. V. (2019) New Technologies for Creation of Electromagnetic Radiation Shields Based on Modified Powder, Nanostructured and Film Materials. *Doklady BGUIR*. 120 (2), 85–99 (in Russian).
13. Ayad H., Boiprav O., Lynkou L. (2020) *Electromagnetic Shields Based on Powdered Coal-Containing Materials*. Minsk, Bestprint Publ.
14. Huang Y., Chen S., Ma R., Cheng Y., Jin L., Chen G. (2021) Coal-Based Carbon Composite with Excellent Electromagnetic-Shielding Properties Prepared from Modification of Coal with D-A Reaction. *Advanced Composites and Hybrid Materials*. DOI: 10.1007/s42114-021-00290-5.
15. Shukla V. (2019) Review of Electromagnetic Interference Shielding Materials Fabricated by Iron Ingredients. *Nanoscale Advances*. 1, 1640–1671.

Information about the author

Ayad Hisham, PhD, Lecturer of the Electrical Engineering and Electronics Department of the University of Zawia.

Address for correspondence

16418, Libya,
Az-Zawiyah
University of Zawia
Tel. +218 92 740-54-17
E-mail: hishamayadayad@gmail.com
Ayad Hisham