Maistat, Mykyta; Kryvobok, Andrii

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Mykyta Maistat,
Andrii Kryvobok

ANALYSIS OF THE STRUCTURE OF ELECTRICALLY CONDUCTIVE COMPOSITE CERAMICS

The object of the research is electrically conductive ceramics. It aims to analyze the microstructure of electrically conductive ceramic composites based on silicon carbide and investigate the influence of silicon carbide content on their properties. This study is pivotal for enhancing materials used in high-tech applications, particularly in fields where distinct electrical insulation and mechanical characteristics are crucial. The microstructure analysis conducted through scanning electron microscopy confirmed the presence of silicon carbide in all examined ceramic samples, except in those where silicon carbide was not added. Special attention should be given to the sample with 30 % silicon carbide, distinguished by the lowest open porosity. These findings are corroborated by previous research where this sample exhibited superior properties: open porosity – 12.51 %, water absorption – 5.88 %, apparent density – 2.13 g/cm^2, specific resistance – 0.43·10^6 Ω·m. These characteristics indicate low porosity and high structural-physical property values. The results not only affirm the successful incorporation of silicon carbide into the ceramic matrix but also highlight the prospects for applying the researched ceramic materials in areas where electrical insulation and mechanical properties are crucial. Specifically, the sample with 30 % silicon carbide appears particularly promising due to its high characteristics and lower porosity, making it potentially interesting for applications in high-tech industries such as electronics and telecommunications. The conclusions suggest the potential use of these ceramic materials in various high-tech industries where both electrical and mechanical properties are essential. The sample with 30 % silicon carbide, with its exceptional characteristics, holds potential for applications in advanced technologies. Further research in this direction could lead to the development of new materials for effective radiofrequency absorption, finding broad applications in different technological fields.

Keywords: *electrically conductive ceramics, microstructure, silicon carbide, SiC, porosity, electrical insulation properties, electron microscopy, microstructure.*

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1. Introduction

With the growing use of electronic equipment and wireless devices, the threat of electromagnetic radiation (EMR) pollution is becoming more relevant [1]. The effects of excessive EMR not only affect the operation of technical devices, but also pose a threat to human health [2, 3]. In this regard, much attention is paid to the development of materials for effective shielding of electromagnetic interference (EMF), capable of preventing excessive EMR [4]. The main method of functionalization of such materials is to reduce the transmission of electromagnetic waves due to their reflectivity and deepening [5, 6].

In modern research, the main materials for combating electromagnetic interference are metals and polymer-based composites [7, 8]. Metals, due to their weight and susceptibility to corrosion, have their limitations in application [9–11]. Defects in heat resistance and strength are associated with polymer composites [12]. Therefore, even in modern production, materials based on metals and polymer composites do not always meet the requirements for highly effective shielding in conditions of high temperatures and other aggressive factors. In particular, for aircraft in the aerospace industry, there is an important need for high-temperature-resistant components with exceptional characteristics. Among various materials that demonstrate high shielding efficiency, composites based on silicon carbide (SiC) stand out for their lightness, excellent heat resistance, mechanical properties, and tunable electromagnetic characteristics [13–15], making them promising candidates for shielding in high-temperature conditions.

Considering the above, *the object of research* is conductive composite ceramics. *The aim of this research* is to study the microstructure of conductive composite ceramics with 10 %, 20 % and 30 % SiC content.

2. Materials and Methods

To conduct a study of the microstructure of electrically conductive composite ceramics based on silicon carbide (SiC), samples with different SiC content (10 %, 20 %, and 30 %), as well as a sample without silicon carbide, were used. The sample manufacturing procedure included the following stages.

The specified amount of raw materials was weighed in the required amount, 10 %, 20 %, and 30 % SiC were added to the raw materials, except for the sample without SiC, and subjected to wet grinding in a layer mill. The resulting slip was dried in a drying cabinet, crushed and passed through a sieve No. 05. The finished press powder for SiC composite ceramics, moistened to 8 %, was weighed and poured into a press mold, the pressure force was 18–20 MPa. The obtained raw material was dried in a drying cabinet. The finished semi-finished product was fired in a silite furnace at a firing temperature of 1120–1140 °C, with exposure at the maximum temperature for 5–10 min [16]. The mass composition of raw materials for the production of electrically conductive composite ceramics from SiC is presented in the Table 1.

Table 1

Mass composition of raw materials for the production of electrically conductive composite ceramics from SiC

The name of the raw material	Mass fraction of materials, wt. %			
	without SiC	10 % SiC	20 % SiC	30 % SiC
Andriivska clay	43.00	38.70	34.40	30.10
Granite screenings	13.00	11.70	10.40	9.10
Quartz sand	29.04	26.14	23.23	20.33
Crushed chalk	8.03	7.23	6.42	5.62
Tile battle	6.93	6.24	5.54	4.85
Silicon carbide	0	10.00	20.00	30.00

The study of the microstructure of the test samples was carried out by the method of raster electron microscopy using a scanning electron microscope PhenomPro (USA).

3. Results and Discussion

The microstructure of the obtained ceramics was studied by scanning electron microscopy. Photomicrographs of fractures of test samples are shown in Fig. 1.

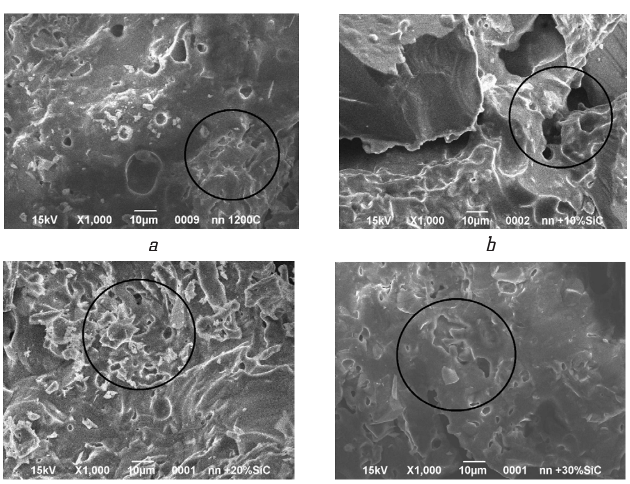

Fig. 1. Microstructure of the sample: *a* – without SiC; *b* – with 10 % SiC; *c* – with 20 % SiC; *d* – with 30 % SiC

In the indicated photomicrographs (Fig. 1, *b*–*d*), it is possible to note the visible presence of silicon carbide (SiC) in all tested samples, except for the one where SiC was not added (Fig. 1, *a*). This indicates the inclusion of silicon carbide in the matrix of ceramic materials.

Among the samples to which silicon carbide was added, it can be seen that the sample with 30 % SiC (Fig. 1, *d*) has the lowest open porosity. This is also confirmed by a previous study [16], which indicated its characteristics: open porosity – 12.51 %, water absorption – 5.88 %, apparent density – 2.13 g/cm^2, resistivity – $0.43 \cdot 10^6$ Ω·m.

The obtained results are distinguished by the high efficiency of electromagnetic interference shielding with the help of SiC. Compared to the literature, which reports efficiency values in the range of 20–22 dB, our 30 % SiC samples show values that can exceed 22 dB, indicating the high potential of the material.

These results also have practical implications for the aerospace industry and high-temperature environments. Electrically conductive SiC composite ceramics can be effectively used for shielding against electromagnetic interference in high-temperature environments. The results of the research can also be used as ceramic tiles to weaken the electric component of the electromagnetic field inside rooms located in the area of radio radiation sources. It is also possible to use it for environmental purposes, to reduce the intensity of the electromagnetic field outside the premises where work with electromagnetic radiation is carried out.

A limitation of research and use is the particle size composition of SiC, which can affect the overall properties of the material. Additional factors such as the distribution of SiC in the matrix may also affect the results.

In the conditions of martial law, the study of the microstructure of samples caused difficulties due to the problem of access to laboratory resources, the limitation of the possibility of conducting experiments and exchanging scientific information. In addition, the conditions of martial law significantly affected the availability of equipment and the possibility of scientific cooperation with other institutions or researchers.

Further research will include optimization of the SiC content to achieve the maximum shielding effect. Also, studying the effect of other additives on the electromagnetic characteristics of the material can expand its capabilities.

4. Conclusions

As a result of the microstructure analysis, carried out with the help of scanning electron microscopy, the presence of SiC has been established in all investigated electrically conductive composite ceramic materials (except where silicon carbide was not added).

The obtained results not only confirm the successful inclusion of silicon carbide in the ceramic matrix, but also indicate the prospects for the use of the investigated ceramic materials in industries where electrical insulation and mechanical properties are important.

In particular, the 30 % SiC sample appears particularly promising due to its high performance and lower porosity, making it potentially interesting for applications in high-tech industries such as electronics and telecommunications.

Further research in this area can contribute to the further development of new materials for effective radio absorption and find wide application in various technological fields.

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Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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Data availability

The manuscript has no associated data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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✉***Mykyta Maistat,*** *Postgraduate Student, Department of Technology of Ceramics, Refractories, Glass and Enamel, National Technical University «Kharkiv Polytechnic Institute», Kharkiv, Ukraine, e-mail: aichemict777@gmail.com, ORCID: https://orcid.org/0000-0002-1875-3946*

Andrii Kryvobok, *Postgraduate Student, Department of Technology of Ceramics, Refractories, Glass and Enamel, National Technical University «Kharkiv Polytechnic Institute», Kharkiv, Ukraine, ORCID: https://orcid.org/0000-0001-5878-8732*

✉*Corresponding author*