ABSTRACT

for the degree of a Doctor of Philosophy (PhD) in specialty 6D072300 – "Technical Physics"

Mukhamedova Nuriya Meyramkanovna

The study structure of the phase state and physico-mechanical properties of the material based on silicon and carbon black.

Currently, itis observed intense interest all over the world in the development of new technologies, techniques and methods for producing perspective materials, such as silicon-carbide ceramics for application in the different branches of industry and science. During development of new approaches to produce materials, special attention was paid to the formation of its structure and determination of physical and mechanical parameters of the material to determine a better method for the production of materials.

Relevance of the Research Topic

Currently, Kazakhstani industry goes though large changes, and it leads to the need to create new technologies and techniques for obtaining fundamentally new materials and improving those already in use, that will contribute not only to the development of the scientific field, but also to individual sectors of the economy and industry.

Silicon carbide ceramics has properties such qualities as high thermostability, heat resistance, corrosion stability, wear resistance, resistance to aggressive environments. Also, silicon-carbide research shows that it is endowed with such important characteristics, as high resistance to elevated temperatures, chemical stability, as well as resistance to radiative effect.

Today, the scope of such materials is mechanical engineering, oil and chemical industries, nuclear power and etc. It should be noted that based on silicon carbide are used in power reactors as a layer of a tristructural isotropic coating for nuclear fuel elements, in mechanical engineering as end mechanical seals, as a component of composite armor and disc brakes. In addition, this material is considered as a candidate material for the cladding of fuel rods in nuclear power reactors [1–5].

Many technologies are known to produce materials based on silicon carbide. Standard and globally known techniques and technologies for producing silicon-carbide materials are consist in the impregnation of a graphite billet with liquid silicon, or hot pressing of silicon and carbon using eutectic additives.

Currently, it should be noted that in Kazakhstan there is no production of materials consisting of silicon and carbon and even more so with the use of secondary industrial products as initial components.

Obviously that now, it is relevant to develop a new technology for the production of silicon carbide materials using secondary industrial products, such as graphite and quartz scrap, as initial components.

It is also worth noting that according to the State Program for Industrial and Innovative Development of the Republic of Kazakhstan, approved by the Decree of the President of the Republic of Kazakhstan No. 874 dated August 1, 2014, it is necessary to give a new level of manufacturability to priority sectors of the manufacturing industry and create a basis for their development.

The purpose of this dissertation work is studying developed new technology for obtaining silicon carbide materials using secondary industrial products as initial components, the properties of which are not inferior to similar materials obtained by known methods.

To achieve this goal, the following **key challenges and investigations** were set:

– obtain silicon carbide ceramics by induction heating;

– obtain silicon carbide ceramics by spark plasma sintering;

– estimate the amount of the SiC phase formed in the prototypes obtained by induction heating and SPS;

– study the physical and mechanical characteristics of the obtained silicon carbide material;

– to establish the features of the influence of parameters of solid-phase sintering on the structure and properties of the obtained ceramic material.

Key Provisions for Defense

1. Influence of the main thermodynamic parameters of sintering on changes in the structural-phase composition and in obtained silicon carbide ceramics.
2. Change in physical and mechanical properties of silicon-carbide ceramics depending on basic thermodynamic parameters.
3. Physical and technological features of the obtained ceramic material depending on sintering modes.

The scientific novelty of the dissertation work is that:

1. Method for producing silicon-carbide material using secondary industrial products as initial components has been first developed (Patent of the Republic of Kazakhstan for the invention No. 32057. bull. No. 9, published on May 15, 2017).
2. Silicon-carbide ceramics were first obtained by spark-plasma sintering using quartz and graphite scrap as initial components.
3. Features of the structural-phase state and physico-mechanical properties of silicon carbide ceramics obtained by SPS are established.

Research Subject: structural-phase composition and physical and mechanical properties of silicon-carbide ceramics obtained using the developed sintering method.

Research Object: material from silicon carbide ceramics obtained by induction and spark-plasma sintering of graphite and quartz scrap.

Research Methods:

- Scanning and transmission electronic microscopy;
- X-ray structural analysis;
- Statistical and numerical methods;
- Physical and mechanical methods.

Relevance of Research:

The obtained results can be in demand and used when designing enterprises for the production of silicon-carbide ceramics and manufacturing the products made of it for various industries of Kazakhstan, such as mechanical engineering, nuclear power, oil production, etc.

The developed method of producing a material based on silicon and black carbon using secondary industrial products as initial components is protected by an

author's certificate and can be used by material scientists to create a material having improved physical-mechanical and tribological properties.

The results obtained are applicable in the scientific and educational process, which is confirmed by the presence of acts of implementation in the activities of the branch of the IAE RSE NNC RK and the NcJSC "Shakarim University of Semey".

Author`s Personal Contribution:

Author`s personal contribution consists of setting research tasks, analyzing literature data and patent search, participating in experiments on obtaining samples of silicon-carbide ceramics, calculating initial components based on stoichiometry and heating temperature conditions for induction and spark-plasma sintering. Together with specialists of the IAE Branch of RSE NNS RK, electron microscopic, metallographic, X-ray and physical-mechanical studies of samples of the obtained silicon carbide ceramics were carried out. The analysis of the results obtained and formulation of the main conclusions were carried out jointly with scientific consultants.

Relation of the Topic with the Research Programs Plans

Part of the experimental results of this dissertation work was obtained with the financial support of the State Institution "Committee of Science of the Ministry of Education and Science of the Republic of Kazakhstan" in the framework of the Contract No. 271 dated February 12, 2015 on the topic "Method of obtaining siliconized graphite".

The degree of validity and reliability of the results obtained in the work is ensured by the correctness, accuracy and originality of the tasks set, the use of well-tested experimental methods and research methods, a large amount of experimental data, their statistical processing and comparison of the obtained data with previously published research results of well-known scientists of the CIS and far abroad. The main results of the dissertation work are published in publications recommended by the Committee on Quality Assurance in the Field of Education and Science of the MES RK, in peer-reviewed foreign scientific journals included in the databases of Thomson Reuters, Scopus, and also in collections of materials from international and domestic conferences.

Approbation of the Work Results:

The main results of the dissertation work were presented at 6 international conferences:

1. XXII International Scientific and Technical Conference of Student and Postgraduates "Radio electronics, Electrical Engineering and Energy", National Research University MPEI (Moscow, Russia, February 25-26, 2016);
2. XI International Scientific and Technical Conference “Eurasia Science” (Moscow, Russia, October 31, 2017);
3. XVI Kurchatov Interdisciplinary Youth Scientific School dedicated to the 75th anniversary of the NRC “Kurchatov Institute” (Moscow, Russia, November 6-9, 2018);
4. V International Conference “Fundamental principles of Mechanochemical Technologies” (FBMT-2018) (Novosibirsk, Russia, June 25-28, 2018);

5. VIII International Conference “Semipalatinsk Test Site: Legacy and Prospects for the Development of Scientific and Technical Potential”, National Nuclear Center of the Republic of Kazakhstan (Kurchatov, Kazakhstan, September 11-13, 2018);

6. X International Conference “Semipalatinsk Test Site: Legacy and Prospects for the Development of Scientific and Technical Potential”, National Nuclear Center of the Republic of Kazakhstan (Kurchatov, Kazakhstan, September 7-9, 2021).

Moreover, at 2 contest-conferences:

1. XV R&D Contest-Conference between Young Scientists and Specialists of the RSE NNC RK, National Nuclear Center of the RK, (Kurchatov, Kazakhstan, May 18-20, 2016);

2. XVI R&D Contest-conference Between Young Scientists and Specialists of the RSE NNC RK, National Nuclear Center of the RK, (Kurchatov, Kazakhstan, May 3-5, 2017).

Besides, the main results of the dissertation work were reported and discussed at scientific seminars of the Technical Physics and Thermal Power Engineering Faculty, at joint scientific seminars of the Engineering and Technology Faculty of NAO "Shakarim University of Semey", at the Scientific and Technical Council of NAO "Shakarim University of Semey ”, Kazakh-Polish scientific seminars of PhD students at the Wroclaw University of Science and Technology (Wrocław University of Science and Technology) (Wroclaw, Poland), as well as on scientific and technical councils of the RSE NNC RK and "Institute of Atomic Energy" Branch of the RSE NNC RK.

Publications:

In total, 18 co-authored publications on the topic of the dissertation were published, among them: 8 efforts (7 articles, 1 patent for an invention of the Republic of Kazakhstan) were published in publications recommended by the Committee for Quality Assurance in Education and Science of the MES RK; 1 article published in foreign scientific journals included in the Scopus and Web of Science databases); 3 articles published in other publications, 6 theses and reports in collections of materials of international and republican conferences.

Structure and Scope of Dissertation:

The work consists of introduction, 5 sections, conclusion, the list of references and appendixes. Dissertation work is presented on 114 pages, consists of 73 illustration, 11 tables, 28 formulas and the list of references with 141 items.