Project names: Development of technology for producing Bi-HTS superconductor ceramics with high critical parameters

Relevance: High-temperature superconductors, due to their unique electrophysical properties (conductive, diamagnetic, etc.), are one of the promising materials used in advanced areas of science and technology - energy, electronics, medicine, communications, instrumentation, etc. They are used to create electromagnetic screens, modulators, antennas, switches and filters of microwave and pulse signals, bolometers of the millimeter, submillimeter and infrared radiation ranges, schematic diagrams of ultra-fast computers, sensitive medical tomographs and hypersensitive diagnostic devices capable of responding even to changes in the mental state of a person, and many others. They occupy a special place for the manufacture of current-carrying tapes, wires and cables, as well as in high-current devices. Although HTSP materials are already used in various fields, the problems of widespread use are limited by its cost, the complexity of technological execution and the values of critical parameters. In this regard, the development of an effective technology for the production of ceramic materials with high current carrying capacity and critical temperature is an urgent task for practical application.

Objective: To develop technology and optimize the production modes of Bi-HTS ceramics with high critical temperature and high critical current density.

Expected results: As a result of the research work carried out, a technology will be developed for the production of initial amorphous precursor materials for use in the production of bismuth-containing high-temperature superconducting ceramics with high critical temperature and increased current carrying capacity. A technology for the production of highly dispersed powder materials (nano and micro-sized) based on amorphous precursors will be developed and HTSP ceramics of bismuth-containing cuprate compositions Bi-2212 and Bi-2223 based on micro and nanodisperse powders will be obtained and the modes of introduction of nanodisperse inclusions based on refractory and magnetic materials into ceramics will be optimized. A technology will be developed to increase the texture and density of the ceramic HTSP sample and optimize the technological modes for obtaining an experimental ceramic sample with a high critical temperature and an increased critical current density. The technology of highly active initial amorphous precursor materials of the Bi-2212 and Bi-2223 compositions will be developed for use as a semi-finished raw material in the production of HTSP for various purposes, with a 2 or more times shortened technological regime for the production of HTSP ceramics. Technological modes of synthesis of Bi-HTSP ceramic samples with increased critical current density will be developed and optimized.

The results obtained for 2021-2023. As a result of the conducted research on the production of Bi-HTSP ceramics based on glassy precursors obtained by quenching the melt, the following devices were developed: - a device for obtaining precursors using intense broadband optical radiation, including UV, visible and IR spectra of high intensity; - melting devices under the influence of combined IR and UV laser radiation; - melting devices under the influence of IR heating. In all melting devices, they were carried out without the use of a crucible, in an oxidizing atmosphere, which ensured oxygen enrichment of glassy precursors. At the same time, the rate of formation of HTSP phases Bi-2212 and Bi-2223 increased by 3-4 times, compared with solid-phase or other methods. Single-phase superconducting ceramics Bi-2223 were obtained, which is difficult to achieve by other melt methods, even with prolonged heat treatment. At the same time, it was found that an increase in the content of Ca and Cu cations above the stoichiometric composition leads to an acceleration and completeness of the formation of the high-temperature phase Bi-2223. The study of the critical parameters of HTSP ceramics showed a significantly increased density of the critical transport current than superconducting ceramics obtained by the solid-phase method, the method of co-deposition, etc. High J_c are associated with the formation of defects in ceramics obtained by the glass crystal method. These defects can be used as pinning centers for fixing the flow. HTSP ceramics of the Bi-2223 composition with nanodisperse inclusions based on ferromagnetic materials NiZnFeO, CoFeO, FeO, CuZnFeO with different concentrations were synthesized. At the same time, superconducting ceramics were obtained with twice the density of the critical transport current than ceramics without additives at a temperature of 77 K and up to 4 times higher at a temperature of 30 K. Superconducting experimental samples of long-length tapes using the "powder in a tube" method were obtained on the basis of synthesized HTSP ceramic samples. At the boiling point of liquid nitrogen 77 K, the density of the critical transport current increased for the composition $Bi_{1.6}Pb_{0.4}Sr_2Ca_{2,5}Cu_{3,5}O_y$up to 10 times, measured by the criterion of 1μV/cm, which significantly exceeds the critical currents of ceramic samples.

Based on the results obtained, it can be argued that the most optimal method for producing HTSP ceramics is the method using IR heating to obtain glassy precursors. The advantage of this method is simplicity of execution, low power consumption, reliability, stability and completeness of the output of the high-temperature phase 2223 HTSP, ensuring high transport current, high performance. The developed method can be used to produce superconducting materials for industrial production of products for various purposes.

All tasks planned according to the calendar plan have been fully completed. The following publications were published for 2021-2023.

1 Nogay A., Uskenbaev U., Tatkeyeva G., Aleksandrovsky V., Zhetpisbaev K., Uskenbaev A., Investigation of the Effect of Laser and Optical Radiation on the Formation and Properties of High-Temperature Superconducting Compounds. KarSTU, Proceedings of the University. 2021. - №3. - C. 268-274. (CQAES).

2 Zhetpisbaev K.U., Uskenbaev D.E., Nogai A.S., Serikov T.G., Tolegenova A.S. Temperature burners are made from non-toxic material and nano-pipes. Bulletin of Toraigyrov University. 2021. - №2. - C. 262. (CQAES).

3 Nurbek N.A., Uskenbaev D.E. Device for measuring critical temperature and critical current of high-temperature superconductors. International scientific and theoretical conference “Seifullin readings – 17: “Modern agricultural science: digital transformation”, dedicated to the 30 th anniversary of independence of the Republic

of Kazakhstan. - Nur-Sultan: Kazakh Agrotechnical University named after Saken Seifullin. 2021. - P. 47-48.
4 Uskenbaev D.E., Ibataev Zh.A., Uskenbaev A.D., Zhetpisbaev K.U., Nogai A.A. Kuramynda bismuth bar zhogary temperature askynotkizgishti x-ray dik zhanemicrokurylymdyk zertteuler // Digital transformation training: Education, science, industry. Collection of materials from the international scientific and practical online conference. Almaty: Kazakh National Women's Pedagogical Institute. 2021.
5 Uskenbaev D., Zhetpisbaev K., Nogai A., Beissenov R., Zhetpisbaeva A., Baigisova K., Salmenov E., Nogai A., Turuntay S. Synthesis of High Temperature Superconducting Ceramics in the Bi(Pb)-Sr- Ca-Cu-O System Based on Amorphous Precursors. Eastern-European Journal of Enterprise Technologies. 2022, №4/12 (118), P. 29-37. (Scopus - 47).
6 Uskenbaev D. E., Nogay A. S., Uskenbaev A.D., Zhetpisbaev K. U., Turmantay S. Study of the effect of conditions on the formation and properties of melt-derived high-temperature superconducting compounds. Bulletin of Toraigyrs University. Energy series. 2022. - №3. - P.186-199. (CQAES).
7 Uskenbaev D.E., IbataevZh.A., Nogai A.A., Uskenbaev A.D. Prospects for producing HTSC ceramics based on bismuth. Materials Int. scientific-practical conference named after D.I. Mendeleev, dedicated. 90th anniversary of Professor R. Z. Magaril. Volume 2. Tyumen: TIU, 2022. -P. 170-171.
8 Uskenbaev A.D. Preparation of bismuth high-temperature superconducting ceramics from melt and study of properties. International scientific and practical conference. “Seifullin readings – 18: “Youth and science - a look into the future.” 2022. - V. I, part VI. -P. 41-44.
9 Uskenbaev D.E. X-ray studies of bismuth superconducting ceramics obtained from the glass phase under the influence of IR radiation. International scientific and practical conference. “Seifullin readings – 18 (2): “Science of the 21st century - the era of transformation” 2022 - V. I, part VI. -P. 273-276.
10 Sarsenbaeva M.B., Dzhusupova A.A., Uskenbaev D.E. Synthesis and critical properties of bismuth high-temperature superconductor of compositions 2234 and 2245. International scientific and practical conference. “Seifullin readings – 18(2): “Science of the 21st century - the era of transformation.” 2022. - V. II, part I. - P. 162-164.
11 Uskenbaev D., NogaiA. S., Uskenbayev A., Zhetpisbayev K., Nogai E., Zhumazhanov B., Nogai A., Baigisova K. The effect of nanoscale additives $CoFe_2O_4$ on the current parameters of HTS ceramics $Bi_{1.6}Pb_{0.4}Sr_2Ca_{2.1}Cu_{3.1}O_y$, obtained by the melt method.ChemEngineering. 2023. (Q1, Prozentile 77).
12 Uskenbaev D., Nogai A., Uskenbaev A., Nogai Э., Synthesis and Properties of Bismuth HTS Ceramics Bi-2234 Obtained from a Melt. Byll. KarSU.Series «Phys.». 2023. - № 3(111). – P. 163-170. (CQAES).
13 Baitelesov S., Uskenbaev D.E., Nogai A.S., Nogai E.A. X-ray, microstructural studies and properties of a bismuth superconductor obtained under the influence of IR radiation. Materials of the international scientific and practical conference “Seifullin

Readings – 19”, dedicated to the 110 th anniversary of M.A. Gendelman." - 2023.- T.I, Part V.- P. 150-152.
14 Sarsenbaeva M.B., Dzhusupova A.A., Uskenbaev D.E. Study of the influence of nanoadditives on the critical parameters of Bi-HTSC. Materials of the international scientific and practical conference “Seifullin Readings – 19”, dedicated to the 110th anniversary of M.A. Gendelman." - 2023.- T.I, Part V.- P. 143-145.
15 Patent for invention. Uskenbaev D.E., Nogai A.S., Uskenbaev A.D., Nogai E.A. A method for producing high-temperature superconducting ceramics Bi-2223 from a melt. Patent for invention. Application No. 2022/0578.1 dated 09/27/2022. In Print.
16 Patent for utility model. Uskenbaev D.E., Nogai A.S., Uskenbaev A.D., Nogai E.A. Method for producing HTSC ceramic composition $Bi_{1.6}Pb_{0.4}Sr_2Ca_{2,25}Cu_{3,25}O_y$ with hight texture. Patent for a utility model №.8711. Application 2023/0791.2 dated 24/10/2023.

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Information for potential users: Using the developed technology, it is possible to obtain massive high-current HTS ceramics for a wide range of applications. As well as superconducting tapes, wires and cables of great length for conductive products and for use in high-current devices. The technology can also be used to produce destructive materials for various purposes with special electrophysical properties – ferroelectrics, piezoelectrics, thermoelements, ferromagnets, solid electrolytes, etc.