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RECEPTION WITH SOLAR ENERGY AND STUDY OF PHASE COMPOSITION OF HIGH-TEMPERATURE SUPERCONDUCTORS HOMOLOGOUS SERIES $\text{Bi}_{1,7}\text{Pb}_{0,3}\text{Sr}_2\text{Ca}_{(n-1)}\text{Cu}_n\text{O}_y$ ($n = 3-20$)

Abstract. The effect of solar radiation on the formation and properties of high-temperature superconducting phases of homologous series $\text{Bi}_{1,7}\text{Pb}_{0,3}\text{Sr}_2\text{Ca}_{(n-1)}\text{Cu}_n\text{O}_y$ ($n = 3-20$) is researched. The dependence of the completeness of HTSC phase synthesis on time-temperature conditions within the range of 846–848 °C. 3–120 hours. The formation defined $\approx 90\%$, in 2223 and 2234 phases. The synthesis under the influence concentrated solar radiation allowed to obtain stable high-temperature superconducting materials with $T_c > (107 \div 151)$ K. The prospects for the use of solar technology is determined for the synthesis of a number of high-temperature superconductors $\text{Bi}_{1,7}\text{Pb}_{0,3}\text{Sr}_2\text{Ca}_{(n-1)}\text{Cu}_n\text{O}_y$ ($n = 3-20$).

Keywords: solar radiation, high-temperature superconductors, HTS materials.

Introduction

High-temperature superconductors based on the system Bi-Pb-Sr-Ca-Cu-O constitute a homologous series represented by the formula $\text{Bi}_{1,7}\text{Pb}_{0,3}\text{Sr}_2\text{Ca}_{(n-1)}\text{Cu}_n\text{O}_y$. There are relatively detailed studies on conditions of synthesis and properties of HTSC that start from the beginning of this series

$n = 1-4$, and very limited information on properties of HTSC phases with $n > 4$. Revealed direct correlation between the increase in the critical transition temperature to the superconducting condition T_c and increase in “ n ” for a raw $\text{Bi}_{1,7}\text{Pb}_{0,3}\text{Sr}_2\text{Ca}_{(n-1)}\text{Cu}_n\text{O}_y$ ($n = 3-20$) allowed to assume the possibility of formation of HTSC phase with a T_c 107K [1]. The conditions for

the synthesis have a decisive influence on the critical properties of high-temperature superconductors. The most common method of synthesis of high-temperature superconductors in the solid phase has significant limitations imposed by the diffusion mechanism of interfacial interactions [2; 3]. Wider possibilities and advantages of melting techniques offer the prospects for finding new technological solutions based on the melted synthesis, that can lead to an increase of critical transition temperature to the superconducting condition and the critical amperage [4]. The increase in T_c can be solved at the expense of a different, compared to the solid phase, phase formation and the nature of the interfacial interactions in the melt and the subsequent reactions in the solid phases during the formation of the target high-temperature superconducting phases. In addition, the reasonable expectation to increase the critical current opportunities lie in the texture and morphology during melt processing control, for example by creating high temperature gradient during the cooling procedure of the melt.

In order to obtain a melt as a heating source high frequency currents are used, induction currents, resistance currents, laser, radiant flux, generated by mercury and xenon lamps [2–4].

Data on the comparative analysis of the impact of spectrum from heating sources on the properties of the materials being processed are very limited, the photosynthesis of inorganic materials are rarely used and specific explanation of the effect is given in [5]. The energy consumption of the heating sources to achieve high temperatures in technological processes under the severe power constraints makes important to appeal to the study of the possibility of using renewable natural sources of energy, including solar radiation. The possibility of using solar radiation for the synthesis of the inorganic materials has been studied in [6].

The positive change of the properties is found and the prospects for use of solar radiation for the synthesis of oxide materials is determined, including a higher fire resistance of complex composi-

tions. However, the explanation of the results of the influence of the solar spectrum on the nature of the formation, interaction phases and properties of the target materials mainly were tentative.

The [7; 8] under the explosion of concentrated solar radiation the synthesization of titanates of pseudobrookite type, mono- and di-lanthanide titanate $P3\bar{6}$ ($P3\bar{6} = \text{La-Lu}$), fluorite solid solutions based on ZrO_2 , HfO_2 the properties of these materials investigated. The distinctions of properties if these materials is defined that synthesized under the influence of solar radiation received by other methods. The changes of the properties allegedly explained by the influence of the solar spectrum on the polarization of the valence electrons and the influence of “nadstehiometrichnogo” oxygen.

Based on these results and the benefits of using concentrated solar radiation as a heating source, inorganic materials synthesis experiment under the influence of solar radiation was distributed to receive high-temperature superconductors homologous series of raw $\text{Bi}_{1,7}\text{Pb}_{0,3}\text{Sr}_2\text{Ca}_{(n-1)}\text{Cu}_n\text{O}_y$ ($n = 3-20$).

Experiment

The synthesis and the study the properties of the precursors and HTSC of the ceramic series $\text{Bi}_{1,7}\text{Pb}_{0,3}\text{Sr}_2\text{Ca}_{(n-1)}\text{Cu}_n\text{O}_y$ ($n = 3-20$). Synthesis of precursors for nominal compounds $\text{Bi}_{1,7}\text{Pb}_{0,3}\text{Sr}_2\text{Ca}_{(n-1)}\text{Cu}_n\text{O}_y$ ($n = 3-20$) was carried out by quenching of the melt obtained under the influence of solar radiation and solar radiation simulators at a density $\approx 680-750 \text{ BT/cm}^2$ (SFAQ-method) [9]. Superconducting ceramic is obtained on the basis of glass-ceramic precursors obtained by ceramic technology. The microstructure and phase composition was examined under the electronic microscopes “NEOPHOT NU-2” Model JEM-1200EX11, JEOL Co., Ltd., Tokyo, Japan, the X-ray diffractometer DRON-UM-1 (CuK α -radiation, Ni-filter).

Phase composition of precursors of the following denominations $\text{Bi}_{1,7}\text{Pb}_{0,3}\text{Sr}_2\text{Ca}_{(n-1)}\text{Cu}_n\text{O}_y$ ($n = 3-20$) in the initial state is represented by the diffraction patterns (Fig. 2a). The weak diffuse reflexes of pre-

cursors with “ $n = 3-5$ ” more clearly manifested when “ $n > 5$ ”. Increase “ n ”, so to say elevated levels of CaO and CuO, leading to destabilization of the glass phase.

After annealing at 500 °C, 3h. the diffraction patterns of ceramics denominations $\text{Bi}_{1,7}\text{Pb}_{0,3}\text{Sr}_2\text{Ca}_{(n-1)}\text{Cu}_n\text{O}_y$ ($n=3-5$) much broadened reflexes phase of 2201 existed: (Figure 2a). In addition, the part of the weak intensity reflexes is defined, which could be attributed to the phase (2212). After annealing at 600 °C, 3h. the phase (2201) was better crystallized and clearly manifested phase appeared (2212). In addition to the reflections belonging to (2201) and (2212) phases, there were a small number of low-intensity reflections present: $2\theta_{\text{CuK}\alpha}$ (20,9; 28,4; 30,1; 36,8; 37,2; 38,2 and unknown phases (X phases), which did not correspond to the phases of 2223, 2234 and the intermediate phases that are involved in the formation of HTSC phases formation reactions at the solid-phase synthesis by [10].

With an increase of the annealing temperature to 700 °C., 3 h. the (2201) phase disappeared; the main phase was (2212) and (2223) phase was present at small portions. With an increase of the annealing time increased to 20 hours the 2212 phase contents increased. Annealing at 845–848 °C, 60–100 h. allowed to obtain $\approx 90\%$ of the mixture $\approx$ HTSC phases (2223) and (2234). The selection of phase (2234), and to determine its amount was difficult because of the close values of $2\theta^\circ$ of these phases. The content of (2212) phase decreased with increasing in annealing time to $\leq 10\%$. The characteristic features of the heat-treated samples were a series of reflections corresponding to 2223, 2234 and, perhaps other phases of HTSC-homology with the unit cell parameters phase identified according to data [11; 12] in assumption of (2223): $a = 5.2832-5.3539$; $b = 5.3698-5.5075$; $c = 36.506-37.3855$; (2289): $a = 5.0545-5.1226$; $b = 5.6696-5.8918$; $c = 36.4798-37.2383$.

The formation of mixtures of homologous phases obtained in the samples synthesized by the

(SFAQ) – method, is not established in the synthesis method of solid-phase reactions. When a solid phase synthesis method is used the superconducting phases are formed by diffusion reactions between 2201 (2212) and intermediates junctions. In the synthesis of the precursors obtained under the use of (SFAQ) – method under the influence of solar radiation, it can be assumed that the rapid quenching of the melt “freezes” existing clusters in the melt cluster-germs of the basic **perovskite** structure of different stoichiometry. On the basis of these embryos in the heat treatment of precursors the HTSC phases homologues are formed.

The effects of formation of phase-homologues were noted previously in synthesized by the use of the same method of fluorite-type solid solutions on the basis of $\text{ZrO}_2(\text{HfO}_2)$ and **P3O** titanate pyrochlore, [7–9]. Probably, the formation of a series of phase-homologues inherent to defect in the crystal structure and their formation involves both the “excess” oxygen and affects of the excited state of electrons that occurs due to the exposure to the melt of the concentrated radiant flux.

The microstructure of the superconducting ceramic compositions had the superconducting material's characteristics lamellar structure (Figure 3). All ceramic compounds under the research had Meissner effect to 184K, that is confirmed by X-ray diffraction data.

Conclusion

Synthesis under the influence of the concentrated radiation allow to obtain stable high-temperature superconducting materials with $T_c > 107\text{K}$.

The lack of intermediate phases, which, according to the solid-phase synthesis 2212, 2223, 2234 phases should take part in their formation, allow to assume formation of different from the solid-state mechanism of HTSC phases of the precursors synthesized under the influence of concentrated solar radiation. The conditions for synthesis are defined in the rapidly melting gradient conditions. The rapid quenching of the melt “freezes” different on the stoichiometry

“germs” on the basis of which the heat treatment of superconducting phases are formed from the series of homologs $\text{Bi}_{1,7}\text{Pb}_{0,3}\text{Sr}_2\text{Ca}_{(n-1)}\text{Cu}_n\text{O}_y$ ($n = 3-20$). These phases can be noted on the diffractograms with the groups of reflexes corresponding to HTSC phases with different parameters of the unit cell.

The formation of the superconducting phases not only in ceramics but also in precursors suggests the following mechanism, which involves the formation of the clusters – “embryos” in the melts with the compound composition and crystalline structure, close to the most stable compound structure

in 2201 and part of the germs, representing the base that participates in the formation of the structure of high-temperature superconducting phases. The differences of stoichiometric clusters – “germ” is influenced by the conditions of synthesis, characterized by a sharp temperature gradient in the melting and quenching the melt.

Melting in gradient temperature conditions can lead to the formation of a melt-homologues clusters of various compositions, which are fixed with melt quenching. These results indicate the possibility of a new “green” synthesis technology of HTS materials.

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