PLASMA DYNAMIC SYNTHESIS OF YTTRIUM-BARIUM CUPRATES FOR HIGH-TEMPERATURE SUPERCONDUCTORS

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In the modern world there is a necessity in use of a large number of the electric power. There are two ways of the solution of this problem: directly increasing the number of generating capacities due to the construction of new power plants, or the transition to superconducting modules [1]. Both ways take place to be, nevertheless, the second way is the most perspective. However, it rests against a creation problem the high-temperature superconductors. Many research and production collectives are engaged in the solution of this problem, including the laboratory of high-temperature superconductivity (HTSC) ENIN TPU.

The new approach connected with application of high-intensity influences is developed in HTSC laboratory (digit plasma, magnetic-pulse pressing, dispergating of powders). The main aim of the laboratory is the development of material synthesis technology, capable to show the superconducting properties at normal conditions. Such a way, the main task of this work is the development of such material synthesis technology which will allow to obtain the product with superconducting properties at enhanced temperatures [2]. The most perspective way in this direction is the obtaining of yttrium - barium cuprates.

In this work the way of the plasma dynamic synthesis of charge mixture for high-temperature superconductors is developed with the use of the coaxial magnetoplasma accelerator of professor Sivkov [3]. The essence of a method consists in the following: initial components of charge mixture (barium hydroxide (Ba(OH)2) and yttrium nitrate (Y(NO3)3)) are loaded into the plasma formation zone of the accelerator where the discharge is burned and formed plasma flow. Copper oxide (CuO) turns out to be as the result of electric copper conductors explosion, and as an additional result of the pure copper erosion from the walls of a copper acceleration channel (AC). Accumulated cooper is oxidized to copper oxide. At the plasma flow development, the specified particles are dispergated due to colliding with camera walls. The necessary composition of charge mixture and the particle sizes are selected at separation of the obtained powder.

The setup (figure 1) is presented in the form of the cylindrical pipe divided into two cameras: the registering camera and the working camera. In the registering camera there is a window through which by using the superhigh-frequency camera (Photron FASTCAM SA1.1) the registration of the process into the chamber is carried out.

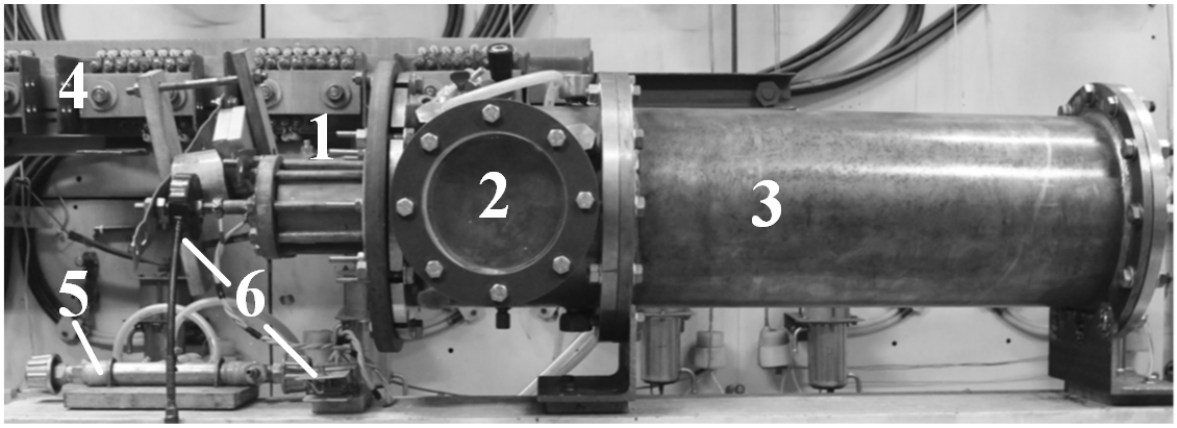

Fig. 1. Experimental setup: 1) CMPA; 2) registering chamber; 3) working chamber; 4) copper buses; 5) gas system; 6) equipment for registration of electrical parameters

The main element of the construction is a coaxial magnetoplasma accelerator (CMPA) which is placed on a flange of the registering camera. The CMPA consists of a typical Z-pinch-type accelerator and the external inductive system. The Z-pinch-type accelerator is the combination of the copper acceleration channel, the copper central electrode and the fiber-glass insulator. The central electrode and the fiber-glass insulator form the plasma formation zone. Initial powdered precursors (charge mixture) are placed in the plasma formation zone before the experiment and during the plasma burning they are involved in the plasma flow motion. Also in the plasma formation zone between central electrode and the AC copper wires are stretched to create the current channel.

The working cycle is the following: at the first moment power keys close and the pulse current starts to flow through the central electrode. After achieving by the increasing current i(t) of some level, fusible copper wires blow up, with the formation of the heavy-current arc discharge (initial plasma). Then the plasma of the heavy-current discharge is compressed by magnetic field of external inductive system, and takes the extended form. The parts of yttrium and barium, loaded into the plasma formation zone and the erosion products, are converted into an ionic state and involved in the plasma flow movement. The final product of reaction under the pressure exits form the AC in the registering chamber, and then in the working camera. The photogram of plasma flow movement in the registering chamber is shown in figure 2. The drawing of the AC edge is given in the top left image to explain whence the plasma flow begins.

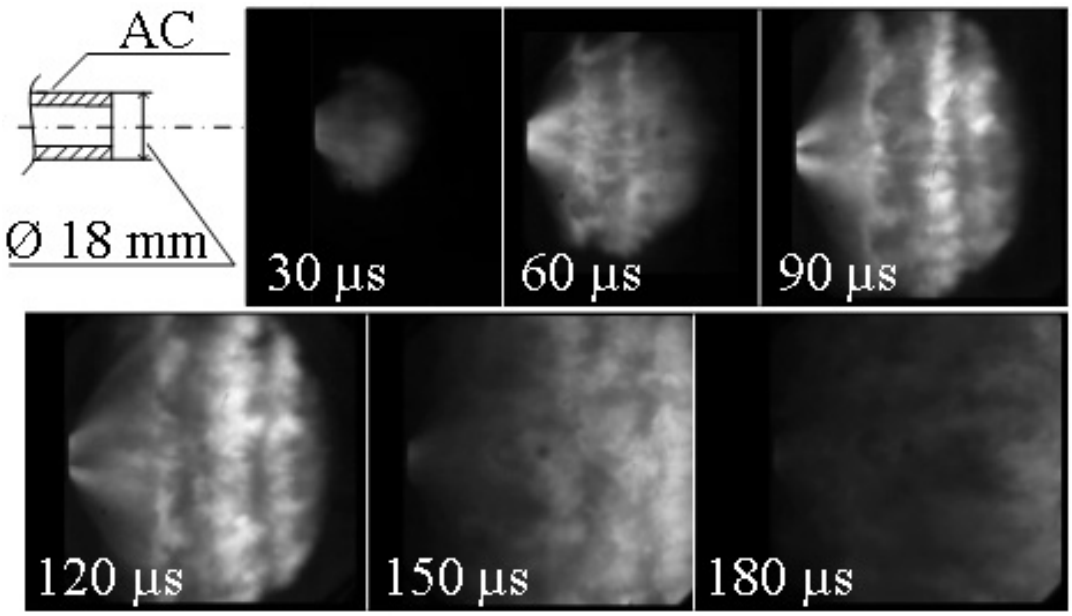

Fig. 2. The photogram of the plasma flow movement in the registering chamber with indication of time intervals from the start of the synthesis process

Figure 2 shows the dynamic of the plasma flow development directly in the registering camera filled with air atmosphere at normal conditions. The plasma contains particles of precursors, copper and copper oxide. Particles are accelerated in a plasma flow. At interaction of oxide particles with camera walls an intensive dispergating of the particles is started. It is promoted by a high temperature created in the plasma flow. This process leads to a more intensive destruction of large particles. After achieving by the plasma flow a camera back wall there is a reflected wave providing a bigger high uniformity of the powder. The working process duration is about 500 microseconds. The dispersion of powdered oxide

particles were defined with the electronic microscopy. The average size of particles about 200 nanometers is obtained.

The analysis of the obtained phases and the structure of the synthesized powder was carried out on the X-ray diffractometer Shimadzu XRD 7000S (CuKα– radiation). The obtained XRD patterns of synthesized product, the product after annealing, the product after sintering and the peaks position for yttrium-barium cuprates reference are presented in figure 3.

The XRD pattern for the synthesized product consists of many reflexes that can be attributed to initial components of charge mixture and copper particles. No matches with the reference pattern have been found. To exclude different impurities from initial precursors that can be in the final product the annealing of the final product at a temperature of 850°C with the subsequent endurance within an hour has been carried out. This process, in particular, is necessary for the decomposition of difficult barium and yttrium compounds. The following effects were observed as a result of XRD analysis: instead of reflexes attributed to barium hydroxide, there were reflexes that is similar with barium oxide.

To obtain the ceramics sample from the powder after annealing the magnetic-pulse pressing were carried out. After this, the sample has been sintered at a temperature of 960 °C within six hours with controlled cooling of 100 °C/h. The XRD pattern of the ready ceramics sample is also shown in figure 3. The obtained pattern is similar to the reference data for tetra phase of yttrium - barium cuprate, but comparing the received X-ray diffraction with any certain standard wouldn't be true since the base presented in the Search-Match program is very wide and various. It is possible to add that our picture has divergences on the reflexes intensity. It is the result of that the technology is at a development stage and optimal modes only are selected.

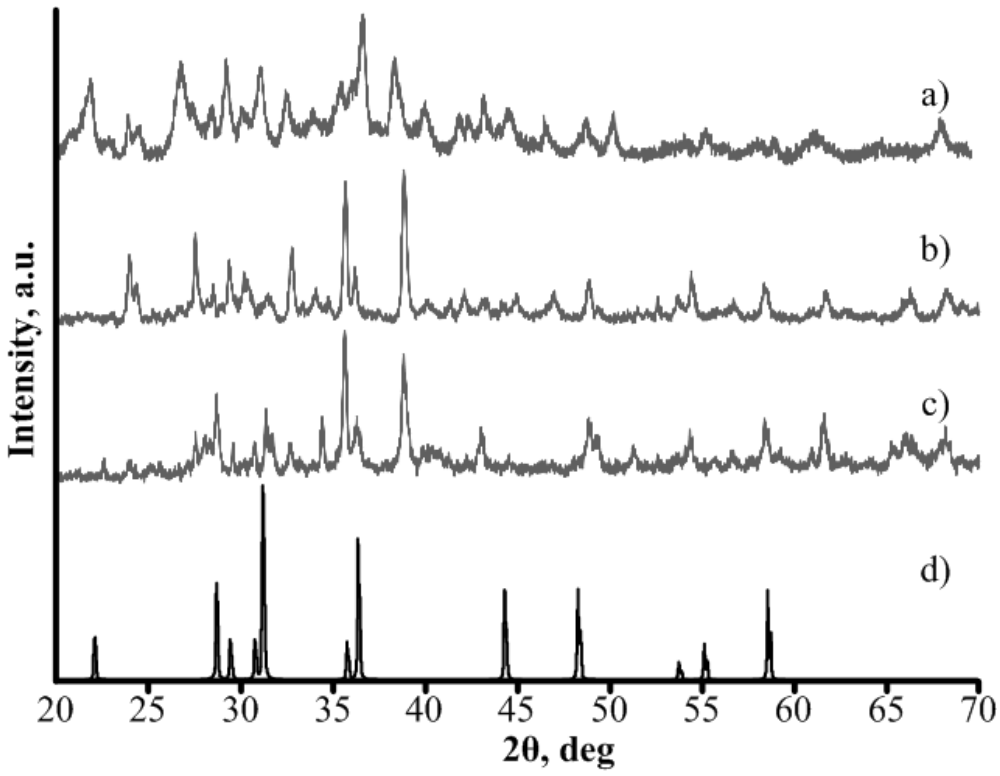

Fig. 3. XRD patterns: a) the synthesized product; b) the product after annealing; c) the ceramic sample after sintering; d) the yttrium-barium cuprates reference

In addition, at the final product there is a quantity of alien impurity leading to an increase in a temperature interval of a sample transition in a superconducting state as a result [5]. It should be noted that with the temperature approach to an absolute zero, the sample resistance will "aspire" to the residual resistance which, in turn, depends on the structure of initial precursors and perfection of the final product.

That's why in the second series of experiments the yttrium nitrate annealing with the controlled temperature increasing (no more than 4 °C/min.) to 420 °C, with the subsequent endurance within 40 minutes was carried out. As a result of a heat treatment the pure Y2O3 oxide was obtained. Thus the initial precursors of a charge mixture without impurities were received.

As a result of this work it is possible to make the following conclusions:

1. The rapid single-stage process of powdered charge mixture synthesis with the duration of no more than 500 microseconds were developed.
2. The obtained ceramic has nanocrystalline structure that finally can significantly effect on the sample transition temperature in a superconducting state.
3. The ceramic is characterized by crystalline phases which are typical for the reference phases of yttrium - barium cuprates.
4. Reducing a temperature transition interval and decreasing a superconductor residual resistance, it is necessary to the make preliminary annealing of initial components, for the "parasitic" impurity elimination.
5. The possibility of material synthesis and production of high-temperature superconductors ceramics based on yttrium-barium cuprates with the use of high-intensity technologies is shown.

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