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Q1HTSC Superconducting Bi-Pb-Sr-Ca-Cu-O and MgB_2 Compositions Fabricated by Hot Shock Wave Consolidation and Solar Melt Quenching Technologies

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ABSTRACT

The possibility of increasing of the critical temperatures T_c of superconducting precursors in samples of Bi-Pb-Sr-Ca-Cu-O and MgB_2 superconducting systems, fabricated using hot shock wave consolidation technology (HSWC) and solar energy for melting, and following superfast quenching of the melt, was investigated using vibrating torsional magnetometry methods. By using HSWC technology for the synthesis of Bi-Pb-Sr-Ca-Cu-O samples, the critical temperature T_c of potential superconducting precursor transition to a superconducting state was increased from T_c=107 K in the starting sample, to T_c=138 K.

In the Bi-Pb-Sr-Ca-Cu-O superconducting system samples, synthesized using solar energy for the melting and following superfast quenching of the melt, superconducting precursors with T_c more than 200 K were detected. The analysis of the nature of the obtained dependences, and their comparison with other available results associated with the processes in the vicinity of critical temperature T_c, allows one to conclude that there is a possibility for the existence of high-temperature superconducting precursors with T_c more than 200 K in samples of this system.

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Introduction

After the epoch-making discovery of high-temperature superconductors (HTSC) by Müller and Bednorz in 1986, significant efforts have been devoted worldwide to further increase the critical temperature of superconducting transition T_c, with the aim of reaching room temperature. The use of HTSCs with a T_c higher than those currently used (YBaCuO and MgB_2, for example) would lead to the development of new technological advances, opening up numerous opportunities in electronics and energetics.

From this point of view, the Bi-Pb-Sr-Ca-Cu-O system attracts particular interest, as it is characterized by high T_c=107 K and the record-high second critical magnetic field H_{c2} ~ 150 T. According to some studies (Yu *et al.*, 2019; Pelc *et al.,* 2018; Pelc *et al.*, 2019), the universal behavior of the superconducting (SC) precursor was revealed, signifying the proliferation of SC clusters as a result of the inherent intrinsic inhomogeneity of cuprates. Understanding its nature is very important for the fabrication of new HTSC materials with a T_c close to room temperature.

The nature of the SC precursors in the cuprates has been the subject of numerous investigations. Different superconducting experimental methods have led to different conclusions on the temperature range of superconducting fluctuations. The main challenge was in the separation of the SC response from complex normal state behavior. For this aim a torque magnetometry method was used (Yu *et al*., 2019), which is a unique thermodynamical probe with extremely high sensitivity to SC diamagnetism. In torque magnetometry, the magnetization M is deduced from the mechanical torque $\tau = M\ H \sin\alpha$, where α is the angle between M and H, experienced by a crystal in an external magnetic field H. The torque is measured as a function of temperature (T), magnetic field strength (H), and orientation of the sample with respect to the field direction. This approach completely removes normal-state contributions, allowing one to trace the diamagnetic signal above T_c with great precision. As discussed in Yu *et al*. (2019), one could understand the unusual emergence of the SC precursors by noting that the cuprates are lamellar, perovskite-derived materials that are intrinsically inhomogeneous at the nanoscale distances. Evidence for the inhomogeneity was observed in scanning tunneling microscopy (STM) and nuclear magnetic resonance (Yu *et al*., 2019). Consequently, some of the spatially inhomogeneous SC gaps “survive” in the form of the SC precursor clusters at temperatures well above T_c. As the temperature decreases, these SC precursor clusters proliferate and grow in size, and eventually percolate near T_c.

In works (Chigvinadze *et al.*, 2018; Mamniashvili *et al.*, 2015; Gegechkori *et al.,* 2017; Gulamova *et al.,* 2012), two special technologies were discussed which were applied to synthesize HTSC samples with increased local inhomogeneities. The first of them is HSWC technology (Chigvinadze *et al.*, 2018), which was successfully applied for the fast fabrication of superconducting MgB_2 samples, avoiding long-time solid-state reaction procedures (Mamniashvili *et al.*, 2015; Gegechkori *et al.,* 2017). HSWC technology was used for the modification of microstructure, the introduction of efficient pinning centers, and the enhancement of the intrinsic inhomogeneity of HTSC samples.

One more special technology applied to synthesize HTSC samples with the increased local inhomogeneities is the solar fast alloy quenching technology (SFAQ-T) discussed in Gulamova *et al.* (2012). Based on glass-crystal and X-ray amorphous precursors, the HTSC samples were synthesized by quenching a melt produced by the heating of precursors with the solar radiation at low temperatures. The decomposition-resistant textured superconducting samples of $Bi_{1.7}Pb_{0.3}Sr_2Ca_{(n-1)}Cu_nO_{10-y}$ (n=2-30) systems with the critical temperatures of the superconducting transitions more than 200 K were fabricated (Chigvinadze *et al.*, 2017).

To determine the critical temperatures of the SC transitions Tc of the samples obtained by both technologies, the original torsional oscillation magnetometry method in applied magnetic fields was realized using an automated multipurpose device (Ashimov & Chigvinadze, 2002), having sensitivity comparable with that of a SQUID magnetometer. The investigation of the potential possibilities of the vibrating reed (VR) magnetometry method for similar aims was carried out in other works (Chigvinadze *et al.*, 2019; Esquinazi, 1991).

Results and Discussion

1. Superconducting Precursors in Bi-Pb-Sr-Ca-Cu-O Compositions Fabricated by HSWC Technology

Following the work Chigvinadze *et al.* (2018), the novelty of the proposed HSWC technology is in the consolidation of high-density bulk samples from the mixtures of the superconducting powders, with dimensions of the order of Æ~2-5 mm, L~ 50-70 mm. The process of consolidation was performed in two stages: First, the explosive pressing of powder precursor mixtures was made at

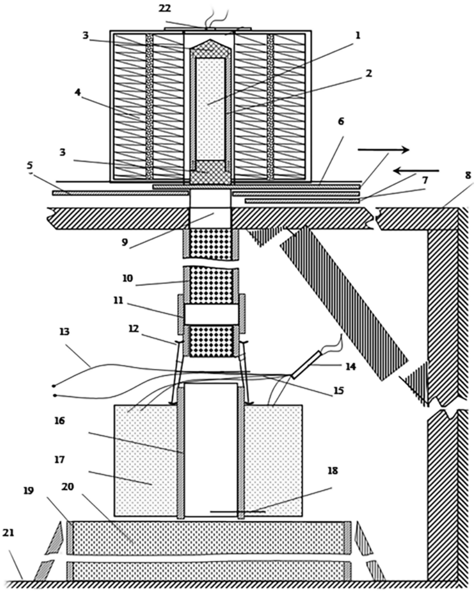

Fig. 1. Set-up of hot explosive consolidating device.

1. Consolidating powder material; 2. Cylindrical steel container, 3. Plugs of steel container, 4. Heating nichrome wires of furnace, 5. Opening and closing movement of furnace, 6. Opening sheet of furnace, 7. Closing sheet of furnace, 8. Basic steel construction of device, 9. Steel feeding tube for samples. 10. Movement tube for heated container, 11. Connecting tube from rub, 12. Accessory for fixing explosive charge, 13. Circle fixing passing of cylindrical ampoule, 14. Electric detonator to initiate, 15. Detonation cord, 16. Flying tube, thermo-isolator, 17. Explosive material charge, 18. Hard metal limiter for fixing the limit state of the ampoule, 19. Exploded cylindrical ampoule receptor, 20. Inert sand, 21. Experimental camera support floor, 22. Thermocouple.

room temperature, with 5-20 GPa loading to increase the initial density and to activate the surfaces of the mixture particles. At the next stage, an obtained cylindrical sample was pressed by an explosive wave pressure of 5-10 GPa at 700-800^{o}C.

The experimental set-up is presented in Figure 1. (Gegechkori *et al*., 2017).

The study of superconducting characteristics shows that after the explosive wave, the material retains superconductivity and the explosive pressing of powder precursor mixtures at room temperature, with 5 GPa, 7 GPa, and 12 GPa pressure loading, does not significantly change the superconducting state of the material. After the explosion, a pronounced texture was formed, which, with the increased temperature of up to 700-800^{o}C at the same applied pressures, could result in the increase of T_c.

The T_c of superconducting transitions were measured using the original supersensitive magneto-mechanical torsional method, through an automated multipurpose device (Ashimov & Chigvinadze, 2002), having sensitivity comparable with that of a SQUID magnetometer. The investigations were carried out operating at low-frequency axially-torsion oscillations (0.1÷1 Hz) in a permanent magnetic field with the strength H, and demonstrated a significant background effect on the experiment, the value of H, the initial orientation of the sample, and the direction of the temperature variation of a sample (cooling or warming) on the obtained results.

The method of axial-torsion oscillations magnetometry was firstly used for the investigation of energy losses (dissipation) in the mixed state of hard superconductors (Ashimov & Chigvinadze, 2002), when a high sensitivity of the torsion system (10^{-17} W) was shown. Using this method, the superconducting phase transition temperature T_c was determined not only by the frequency $\omega=2\pi/t$ of the superconductor oscillating in a permanent magnetic field H, but also by the character of the dissipative process $\delta(T)$ dependence, where δ is the logarithmic decrement of the attenuation of oscillations. These two characteristics t(T) and $\delta(T)$, being measured in parallel, complement each other and provide information on the presence or absence of the magnetic vortex threads in a sample within the study, allowing one to judge the SC state of a sample.

In Figure 2 the results of T_c measurements by the low-frequency torsional magnetometry method for the starting superconducting sample Bi-Pb-Sr-Ca-Cu-O (2223). As is seen, this method gives T_c=107 K. Figure 2 presents the temperature dependence of the oscillation period t of the suspension system, with a superconducting sample suspended by a thin elastic thread and performing axial-torsional oscillations in a magnetic field directed perpendicular to the axis of the superconducting cylinder for the HTSC system Bi/Pb (2223) sample, synthesized by HSWC technology at P≈5 Gpa, 7 gPa and 12 GPa.

Figure 3 shows that at the application of P≈5 Gpa, the critical temperature of transition into superconductive state T_c increases from T_c=107 K up to T_c=115 K (the increase by 8 degrees), the HSWC with P≈7 GPa makes T_c=130 K (the increase by 23 degrees) and the HSWC with P=12 GPa makes T_c=138 K (the increase by 31 degrees).

The use of the HSWC for the creation of new superconducting materials will allow one to synthesize such HTSC systems in which the critical parameters of superconductors can be significantly increased.

The application of a shock wave method for induced enhancement of T_c in superconducting $Bi_{23}Sr_2CaCu_2O_{8+d}$ was also reported by Liu *et al*. (2017). It was further found that T_c increases from 84 K for a pristine sample to 94 K for the sample treated at temperature 1200 K and pressure 31 GPa.

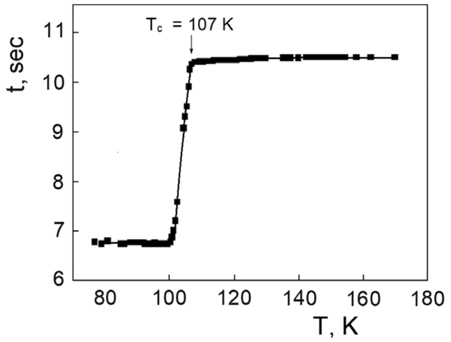

Fig. 2. The temperature dependence of the oscillation t of initial superconducting sample $Bi_{1.7}Pb_{0.3}Sr_2Ca_2Cu_3O_{10-d}$ (2223) suspended by a thin elastic thread and making axial torsional oscillations in a transverse magnetic field, H = 250 Oe.

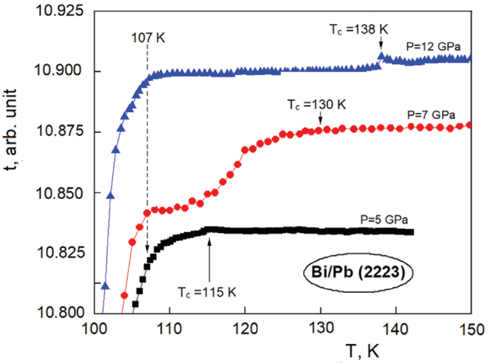

Fig. 3. Dependence of period t on temperature T of superconducting sample suspended on a thin elastic thread and making axial-torsional oscillation in a transverse magnetic field, at P~5 GPa, P~7 GPa and P~12 GPa.

2. Hot Shock Wave Fabrication of Hybrid Superconductive MgB_2 Composites

The rapid development of research of the conductors based on superconducting compound MgB_2 makes them a very real prospect for technical applications at temperatures below 30 K.

Reported achievements of all higher values of the critical current density in wires and tapes at moderate magnetic fields (Jiang *et al*., 2005; Holcomb, 2005) lay out strong hope that soon these conductors may be more economical at helium temperatures than industrial wires and cables based on NbTi and Nb_3Sn.

In the field of applied superconductivity, at temperatures 20–30 K MgB_2 based conductors may seriously push out industrial tape-based high-temperature superconductor (HTSC) materials.

The main way to obtain MgB_2 is a solid-phase synthesis in particular modifications. An example, and one of the most fruitful ones, is synthesis under high pressure (Priknha *et al*., 2003). As HTSC ceramics, compound MgB_2 is brittle and therefore cannot be directly manufactured in the form of wire or ribbon. The most widely used method now to manufacture conductors based on MgB_2 (as for HTSC ceramics) is the method “powder-in-tube” (PIT) (Mamalis *et al.,* 2004). It is mainly used in two ways: in situ and ex situ. In the PIT method, a thoroughly mixed stoichiometric mixture of magnesium and boron powders are pressed into a metallic tube, after which it runs into the wire. A superconducting core of MgB_2 wire is the final result of wire annealing in the average temperature range of 600-950°C. In ex situ PIT method, in contrast, a metal tube filled with already provisionally synthesized compound MgB_2 is stretched into the wire. Both options have their advantages and disadvantages.

In the work of Daraselia *et al.* (2013), a novel method of photo-stimulated solid-state synthesis of oxide materials was developed, enabling a dramatic increase in the solid-state reaction speed. The rate of solid-state reaction appears to be approximately two orders of magnitude higher compared with an ordinary high-temperature solid-state reaction performed in a furnace. The experimental results given in the work of Daraselia *et al.* (2013), provide evidence of the photo-stimulated nature of the performed solid-state reaction, and demonstrate the possibility of production of HTSC and CMR oxides by way of light that is usually limited by the sample thickness - one can reasonably expect this method to be particularly effective in the preparation of oxide films of a high-technological importance.

The paper by Mamniashvili *et al.* (2015) presents the first results of the investigation of the properties of superconducting MgB_2 samples obtained through the hot shock-wave compaction (HSWC) method. Through this method, a similar effect for increasing the speed of solid-state reaction, as in case of using photo-stimulated solid-state synthesis, was obtained. Further, due to the high penetrating capability of shock-waves generated by explosion with intensity of compression 10 GPa, this method allows one to fabricate bulk, high-density and long-body cylindrical billets with a length near to 200 mm and diameter up to 30 mm. The HSWCs of cylindrical billets were conducted using a semi-automatic explosive device created at the Tsulukidze Institute of Mining, allowing one to consolidate different composition precursors near the theoretical density within the temperature range 20- 1200°C, and with an intensity of loading of 5-10 GPa.

The described HSWC method also allows one to produce multilayer cylindrical tubes (pipes) when the gap between the two metallic layers (e.g., Cu) is filled by superconducting MgB_2 composites, a fact which could have important applications in the production of superconducting cables for the simultaneous transport of hydrogen and electrical power in hybrid MgB_2-based electric power transmission lines filled with liquid hydrogen (Gegechkori *et al.,* 2017).

The novelty of the proposed nonconventional approach relies on the fact that the consolidation of solid high-density, long-body cylindrical MgB_2 billets from submicrometer-sized Mg and B powder blends is performed in two stages:

1. At the first stage, a preliminary explosive compression of the precursors is carried out at room temperature, with a loading intensity of 5-10 GPa to increase the initial density and to activate surfaces in the powder blend.

2. At the second stage, the same already pre-densified cylindrical sample is reloaded by a primary explosive shock wave, with a loading intensity of 10 GPa, but at temperatures of around 1000°C.

The first successful HSWC of Mg-B powder blends was performed at 1000°C, with the above-the-melting-point of Mg phase at loading intensity 10 GPa providing the critical temperature of the superconductive transition T_c near 37 K (Figure 4b).

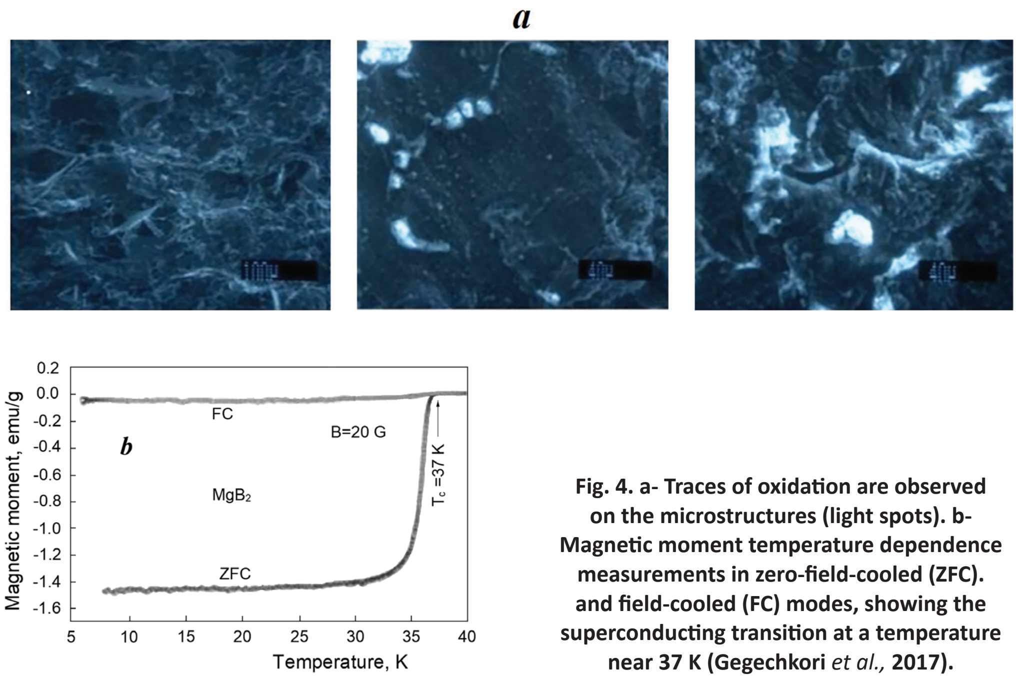

Fig. 4. a- Traces of oxidation are observed on the microstructures (light spots). b- Magnetic moment temperature dependence measurements in zero-field-cooled (ZFC). and field-cooled (FC) modes, showing the superconducting transition at a temperature near 37 K (Gegechkori *et al.,* 2017).

The above confirms the important role of temperature in the formation of the superconductive MgB_2 phase in the whole volume of the sample, and corresponds with the literature data, where only after sintering processes above 900°C does the formation of MgB_2 phase with T_c =40 K take place. The difference of T_c between the HSWC and sintered MgB_2 composites may be explained by the rest period given to the non-reacted Mg and B phases or the existence of oxides in the precursors Figure 4a.

This could be checked by increasing the HSWC temperature or applying further sintering processes. The careful selection of the initial Mg and B phases is also important, and with the consolidation of the Mg-B precursors with the abovementioned corrections, the chance to increase T_c in the HSWC samples essentially increases.

In Figure 5, the views of MgB_2 billets in steel jackets after the previous densification (Figure 5a) and after the HEC procedure (Figure 5b), are shown.

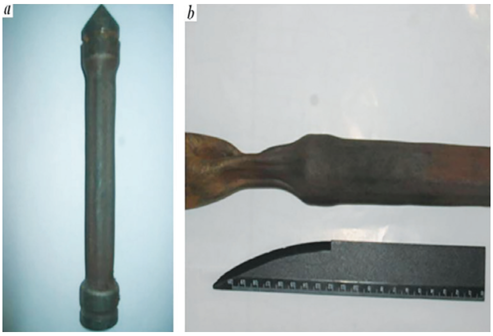

Fig. 5. Views of billets before (a) and after the HSWC procedure at 1000°C and loading intensity 10 GPa (b).

In further experiments, the application of pure Mg and a crystalline and amorphous B powder blend prevented the formation of

MgO in HEC billets and increased the T_c of the obtained MgB_2 composites up to 38.5 K., Figure 6, with pure amorphous boron powder without any post-sintering of the obtained samples.

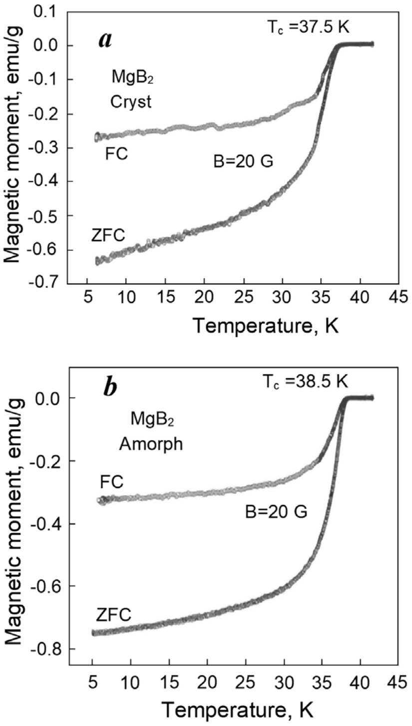

Fig. 6. Temperature dependences of the zero-field cooled (ZFC) and field-cooled (FC) magnetic moment for HSWC MgB_2 composites at 1000°C, with intensity of loading 10 GPa in magnetic field 20 Oe.

For these samples, traces of oxidation (light spots) on microstructures were not observed (Figure 7).

The experiments for the HSWC of precursors were performed under and above the melting point of Mg phase. The consolidation was carried out at 500, 700, 950, and 1000°C with a loading intensity of 10 GPa.

It was experimentally established that the comparatively low-temperature consolidations at 500°C and 700°C would give no results, and the obtained compacts would have no superconducting properties. The application of higher temperatures and consolidation at 1000°C provides the formation of MgB_2 composition throughout the whole volume of HSWC billets, with a maximal value of T_c =38.5 K, without further sintering procedures and corresponding to the literature where T_c =40 K takes place.

Finally, different types of superconducting Cu-MgB_2–Cu tubes for hybrid power transmission lines are demonstrated in Figure 8.

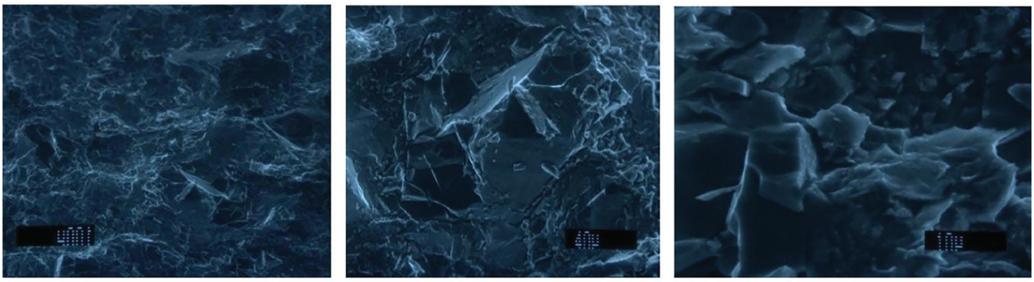

Fig. 7. Microstructures of the HSWC MgB_2 composites with HSWC at 1000°C and loading intensity 10 GPa from pure Mg and B powder blends (Gegechkori *et al.,* 2017).

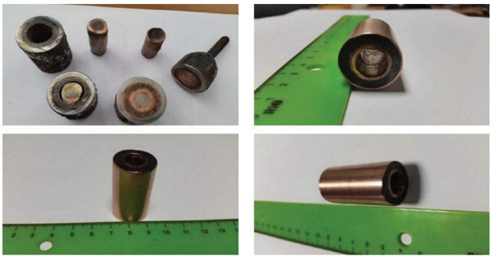

Fig. 8. Cu-MgB_2– Cu superconductive tubes

The novelty of the proposed nonconventional approach relies on the fact that the consolidation of solid high-density, long-body cylindrical MgB_2 billets from submicrometer-sized Mg and B powder blends is performed in two stages.

3. Superconducting Precursors in Bi-Pb-Sr-Ca-Cu-O Compositions Fabricated by SFAQ-T Technology

In the works of Gulamova *et al*. (2012) and Chigvinadze et al. (2019), precursors were synthesized using SFAQ-T technology, quenching the melt obtained by heating with solar radiation at low temperatures (Figure 9).

The characters of the t(T) and δ(T) dependencies for a monophase sample Bi/Pb (2-2-2-3) synthesized by the standard solid-phase reaction, with the critical temperature T_c= 107 K, are shown in Figure 10.

In Figure 11, the typical temperature dependences of the period t and the logarithmic decrement of damping δ of the Bi/Pb sample (2:2:19:20) are presented. All measurements were performed at increasing temperatures from T = 77 K to T = 180 K. As can be seen in Figure 10, the critical temperatures T_c ≈ 128 and 153 K clearly manifest in the dependences of both t(T) and δ(T). Moreover, the transition revealed through the oscillation period t(T) dependence are accompanied by peaks of the damping δ, which are typical for type-II superconductors during the processes of the release of "frozen" vortex filaments and their viscous motion, along with the matrix near the critical temperature. As the temperature rises, other attenuation peaks are also observed on the δ(T) dependence, indicating the presence of the other higher-temperature superconducting phases in this multiphase sample. Critical temperatures with up to T_c= 201 K were subsequently detected in a Bi/Pb sample (2:2:19:20), annealed at 846°C for 47 hours. A fragment of the result with the critical temperature 128 and 153 K is shown in Figure 10.

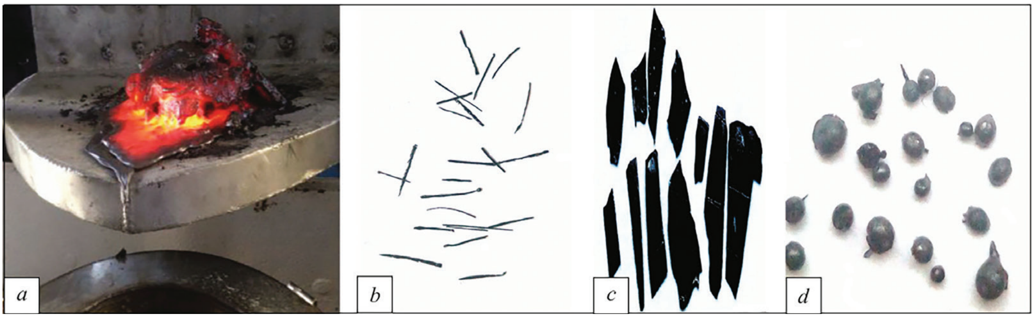

Fig. 9. Melting of a charge with the nominal composition $Bi_{1.7}Pb_{0.3}Sr_2Ca_{(n-1)}Cu_nO_y$ in the Large Solar Furnace (*a*), and precursors obtained through SFAQ-T technology: needles (*b*), plates (*c*), and spherulites (*d*).

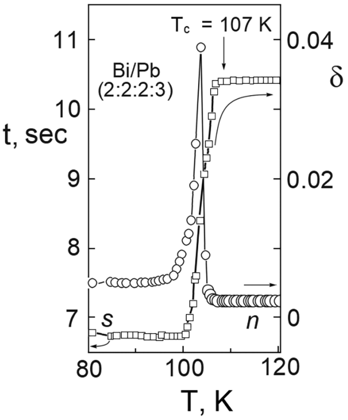

Fig. 10. Temperature dependence of the logarithmic damping decrement d and the period *t* of oscillation in the magnetic field of ceramic samples of the nominal Bi$_{1.7}$Pb$_{0.3}$Sr$_2$Ca$_2$Cu$_3$O$_y$, obtained from precursors synthesized using solar technology.

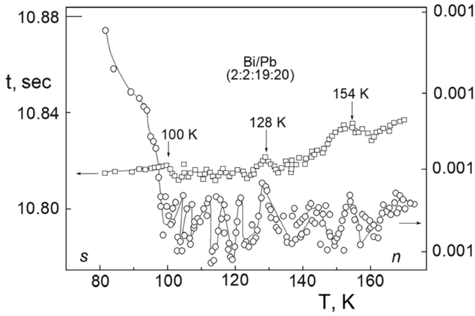

Fig. 11. Temperature dependence of the oscillation period t and the logarithmic damping decrement δ for multiphase Bi/Pb (221920), obtained from SFAQ-T precursors and annealing (846°C - 47 h). The results of measurements when the sample was held for 7 hours in liquid nitrogen in the magnetic field H=150 mT (n-state), as compared with AS-prepared samples (s-state).

It should be noted that, in the case of the multiphase for the Bi/Pb sample (2:2:19:20) in Figure 10, after increasing the temperature, additional attenuation peaks were also observed on the δ(H) dependence, indicating the presence of other HTSC phases in these multiphase samples.

Attention is drawn to the fact that the critical phase temperatures at T = 100, 128, and 154 K are most clearly manifested in peaks due to the attenuation, although closer examination, in particular of the dependence δ(T) in the interval 100 ÷ 170 K, indicates the presence in the sample of a significantly larger number of superconducting phase homologs with close T$_c$.

4. Superconducting Precursors in Bi-Pb-Sr-Ca-Cu-O Compositions Revealed by Vibrating Reed Magnetometry.

The electronic part of the VR acoustic spectrometer contains an acoustic spectrometer operating at a frequency of about 1 kHz, and instruments for powering a permanent magnet (Chigvinadze *et al.*, 2019). The sensitivity of the spectrometer provides measurements of the natural frequency of the sample *f* with an accuracy of ~ 0.1%. In the VR acoustic spectrometer, the electrostatic method of exciting bending oscillations of a sample having the shape of a rectangular plate was used. The electronic equipment of the spectrometer allows measurements to be taken in the mode of the self-excitation of samples at their natural resonant frequencies. The electrode, located in the immediate vicinity of a sample, makes up the capacitance included in the oscillating circuit of the high-frequency generator, and serves simultaneously to excite and detect the oscillations of a sample. Measurements of the resonant frequencies f_r of the sample oscillations make it possible to determine the elastic modulus *E* according to the relation:

$$f_r = k\frac{d}{L^2}\sqrt{\frac{E}{\rho}}$$

where d is the thickness of the sample, L is the length of the oscillating plate, E is the modulus of elasticity, ρ is the density of the sample, and k is a constant factor.

The variation of the square of the resonant oscillation frequency (f^2) of a sample can be considered in the framework of the so-called magneto-mechanical approach (Esquinazi, 1991), according to which, when a superconducting sample is displaced relative to the external magnetic field H, a restoring mechanical force acts on each “pinned” magnetic vortex. As a result, the oscillation frequency of the entire sample changes by Δf(H), depending on the density of the fixed vortices, the moment of inertia of the superconductor, and its volume. The dependence of the elastic modulus E of the substrate-sample system (in units of f^2) on the magnitude of the magnetic field gives information on the elastic interaction of the Abrikosov vortex lattice with the crystal lattice. This is a convenient method for determining the magnitude of the vortex pinning force. In addition, the f^2(H) dependence provides a simple method for determining the lower critical magnetic field H_{c1} value and the critical temperatures of the superconducting precursors in the multiphase HTSC samples.

The temperature dependences of the square of the natural frequency (f^2) of oscillations of Bi/Pb system (2-2-8-9) and (2-2-19-20) samples on a pure niobium substrate (Chigvinadze *et al.,* 2019) in a magnetic field were measured, Figure 8. In order to separate the effects associated with the penetration of AV into a superconducting sample from the effects of the niobium substrate, the temperature dependence of f^2 of pure niobium was measured.

Measurements were carried out in zero field cooled mode (ZFC-mode) in the magnetic field 300 mT, turned on after the cooling of a sample to 80 K.

It is seen that in the area of ~ 90 - 160 K, in sample (2-2-8-9), as well as in sample (2-2-19-20), there are features, near the temperatures of 95, 101, 115, 128, and 141 K. These features are associated with the existing superconducting high-temperature precursors

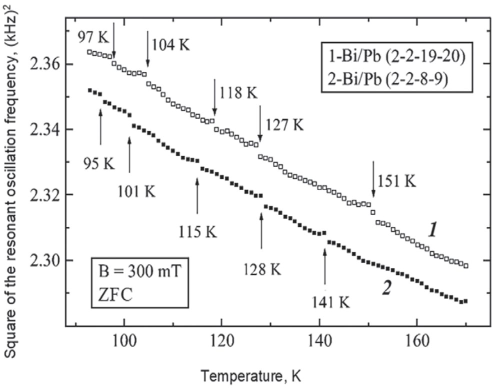

Fig. 12. Temperature dependence of the square of the natural frequencies of the multiphase samples (2-2-19-20) and (2-2-8-9) in the magnetic field of 300 mT.

in the multi-phase samples of the $Bi_{1,7}Pb_{0,3}Sr_2Ca_{n-1}Cu_nO_y$ system, which are absent in case of a single-phase sample (2-2-2-3) synthesized by solid phase technology. Thus, it can be concluded that in the (2-2-8-9) and (2-2-19-20), there are four different superconducting precursor phases. Comparing features in Figures 11 and 12, it can be seen that they are in definite correspondence, but in the case of Figure 12, these features are more clearly separated and visible. This observation could be considered as further confirmation, by the VR magnetometry method, of the existence of high-temperature precursors in multiphase samples of the $Bi_{1.7}Pb_{0.3}Sr_2Ca_{(n-1)}Cu_nO_y$ system, and, in addition, that it shows the potential advantages of application of the VR method to study superconducting precursors in multiphase HTSC samples.

Conclusion

1. The possibility of increasing T_c in HTSC samples of the Bi-Pb-Sr-Ca-Cu-O systems, fabricated using HSWC technology and measured by the vibrating torsional magnetometry method, was studied. The advantages of HSWC technology over traditional technologies for the synthesis of superconducting composites are shown. A critical temperature for the potential superconducting precursor T_c of transition to a superconducting state increased from T_c=107 K (starting sample) to T_c=138 K, using the HSWC technology for synthesis in a range of pressures from P=5 GPa up to P=12 Gpa, with a 31 K increase of T_c in the case of 12 GPa.

2. The liquid phase HSWC of Mg-B precursors at a temperature of 1000°C, provides the formation of the MgB_2 phase in a whole volume of billets, with a maximal T_c=38.5K. The consolidation of MgB_2 billets above the melting point of Mg, up to 1000^{o}C in a partially liquid matrix of Mg-2B blend, powders. An evaluation and investigation of the structural property relations were made.

3. In the torsional low-frequency and vibrating reed dynamic experiments, in the course of investigating the magnetic properties of multiphase cuprate superconductors $Bi_{1,7}Pb_{0,3}Sr_2Ca_{n-1}Cu_nO_y$ (n=3÷5, 20), synthesized using solar energy and superfast quenching of the melt (SFAQ-T technology), the precursor phases with or near T_c=107-160 were detected. Analysis of the nature of the obtained dependences, and their comparison with other available results associated with the processes in the vicinity of critical temperature T_c, allows one to infer the existence of the high-temperature superconducting precursor phases.

The comparative study of torsional and vibrating reed magnetometries for the evaluation of T_c of the superconducting precursors in the multi-phase HTSC Bi-Pb-Sr-Cu-O system, fabricated by SFAQ-T technology, were also investigated for the first time. It was shown that the results obtained by both methods have sensitivity to the superconducting diamagnetism, making it possible to reveal new superconducting precursor phases above bulk T_c in those samples. Further, as compared with the low-frequency torsional spectroscopy method, the vibrating reed spectroscopy method has potential advantages for the study of the superconducting precursors in multi-phase HTSC ceramics.

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