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# On the origin of Superconducting Precursors in Bi/Pb HTSC Phases Synthesized using Solar and Explosion Energies

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***Abstract*** **- A shot review of results obtained by our group and related ones on the nature of the high-temperature superconducting precursors in the Bi/Pb system was made.**

**The possibility of increasing of the critical temperatures $T_c$ of superconducting precursors in samples of Bi-Pb-Sr-Ca-Cu-O superconducting system fabricated using the hot shock wave consolidation technology (HSWC) and solar energy for melting and following superfast quenching of the melt was investigated by the vibrating torsional magnetometry methods. By using the HSWC technology for synthesis of samples the critical temperature $T_c$ of potential superconducting precursor transition to superconducting state was increased from $T_c$=107 K for 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 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 the high-temperature superconducting precursors with $T_c$ more than 200 K in samples of this system.**

***Index Terms*** **- Critical temperature of superconducting transition, high-temperature superconducting phases, solar technology, vibrating reed**

## INTRODUCTION

After the epoch-making discovery of high-temperature superconductors (HTSC) by Müller and Bednorz in 1986, significant efforts were devoted worldwide to the further increase of the critical temperature of superconducting transition $T_c$ with the aim of reaching room temperatures. The use of HTSCs with $T_c$ higher than those currently used (YBaCuO and $MgB_2$, for example) would lead to the development of a 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 the particular interest because it is characterized by high $T_c$=107 K and the record-high second critical magnetic field $H_{c2}$ ~ 150 T. In [1-3] the universal behavior of the superconducting (SC) precursor was revealed signifying of 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 $T_c$ close to the room temperatures.

The nature of the SC precursors in the cuprates has been the subject of numerous investigations. Different superconducting experimental methods have led to the 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 in [1] a torque magnetometry method was used, which is a unique thermodynamical probe with the extremely high sensitivity to SC diamagnetism. In torque magnetometry, the magnetization M is deduced from the mechanical torque $\tau = M\ H \sin\alpha$, where $\alpha$ 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 of the field direction. This approach completely removes normal-state contributions allowing one to trace the diamagnetic signal above $T_c$ with a great precision. Results show that SC diamagnetism vanishes in an unusual universal manner showing the possibility that this unusual behavior signifies the proliferation of SC clusters as a result of the intrinsic inhomogeneity which is the inherent property of the cuprates. These results are very significant for a number of reasons.

First of all, they constitute an unequivocal thermodynamic probe for the emergence of superconducting precursors in the cuprates, as we observe SC emergence via the diamagnetism, which is the fundamental and prominent characteristics of the superconductivity, and because such experimental approach does not resort to any background normal phase effects. As discussed in [1], 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 [1]. 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 $T_c$. The emergence of superconductivity could be understood as a percolation process, with a temperature scale controlled by the distribution of the SC gaps rather than by $T_c$.

In works [4-7], two special technologies were discussed which were applied to synthesize HTSC samples with the increased local inhomogeneities. First of them is the HSWC technology [4], which was successfully applied also for the fast fabrication of superconducting $MgB_2$ samples avoiding long-time solid-state reaction procedures [5,6]. The HSWC technology was used for the modification of microstructure, the introduction of efficient pinning centers, and the enhancement of intrinsic inhomogeneity of HTSC samples.

In powder mixtures, shock waves lead to an extremely rapid mass transfer and high-velocity collisions among suspended solid particles. Such interparticle collisions result in extreme heating at the point of impact leading to the effective localized melting and to the significant increase in rates of numerous solid-state reactions. As a consequence, the morphology of the initial materials is significantly modified, ultimately resulting in a more compact material. Such a morphology change could lead to the better inter-grain coupling and annealing of intra-grain defects. It opens also the ways to the formation of new HTSC phases at grain boundaries. The application of shock wave pressure proved to be an effective method to generate of the superconducting interfaces [7]. In the work [4], the experimental results of the study of the HTSC samples of the Bi-Pb-Sr-Ca-Cu-O system fabricated by the HSWC technology were presented showing the possibility for the significant increase of their critical temperatures $T_c$.

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 [8]. 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 [9].

To determine the critical temperatures of the SC transitions $T_c$ of these samples obtained by both technologies, the original torsional oscillation magnetometry method in applied magnetic fields was realized using an automated multipurpose device [10], having the sensitivity comparable with that of a SQUID magnetometer. The investigation of the potential possibilities of the vibrating reed (VR) magnetometry method for the similar aims was also carried out in [11,12].

## RESULTS AND DISCUSSION

### *2.1 Superconducting Precursors in Bi-Pb-Sr-Ca-Cu-O Compositions Fabricated by HSWC Technology*

Following the work [4], the novelty of the proposed HSWC technology is in the consolidation of high-density bulk samples from the mixtures of the superconducting powders with the dimensions of the order of ∅~2-5 mm, L~ 50-70 mm. The process of consolidation was performed in two stages: first of all, the explosive pressing of powder precursor mixtures was made at room temperature with 5-20 GPa loading for increasing of the initial density and for the activation of the surfaces of the mixture particles. Then, on the next stage an obtained cylindrical sample was pressed by an explosive wave pressure of 5-10 GPa at 700-800$^o$C.

The study of superconducting characteristics shows that after the action of the explosive wave, the material retains superconductivity and the explosive pressing of powder precursor mixtures at the room temperature with 5 GPa, 7 GPa, and 12 GPa pressure loading does not change significantly the superconducting state of the material. After the explosion, a pronounced texture was formed, which with the increase of temperature 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 by three methods: two of them are the standard methods of $T_c$ measurements: the measurements of magnetic susceptibility $\chi(T)$ and electric resistance R(t) and the third one was the original supersensitive magneto-mechanical torsional method using the automated multipurpose device [9], having the sensitivity comparable with that of a SQUID magnetometer. The investigations were carried out operating at the low-frequency axially-torsion oscillations (0.1÷1 Hz) in a permanent magnetic field with the strength H and showed a significant effect of the background of 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 used axial-torsion instrumentation was especially sensitive to the reorientation of magnetic moments in the materials under the study in the external magnetic fields.

As all HTSCs possess their own magnetic moments, the experiments of this kind were quite informative when studying structural transitions, especially when such transitions were accompanied by the reorientation of magnetic moments including the normal state at $T>T_c$.

The method of axial-torsion oscillations magnetometry was firstly used for the investigation of energy losses (dissipation) in the mixed state of hard superconductors [10], when a quite high sensitivity of the torsion system ($10^{-17}$ W) was shown. The use of these possibilities allowed one to determine of the critical parameters, such as $T_c$ or the first critical field $H_{c1}$, to study the anisotropy of pinning force in high-temperature oxide superconductors, and also the intrinsic magnetic characteristics of HTSC samples. This kind studies allow one the investigation of the issue of the order parameter symmetry, judging the mechanisms of pairing and hence the mechanism of HTSC superconductivity. Besides this, the study of the dissipative processes in the vicinity of $T_c$, allows one to observe and investigate the effects of melting of the Abrikosov magnetic vortex lattice in HTSC. 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 of the dissipative process $\delta(T)$ dependence, where $\delta$ is the logarithmic decrement of attenuation of oscillations. These two characteristics t(T) and $\delta(T)$, being measured in parallel, complement each other providing information on the presence or absence of the magnetic vortex threads in a sample under the study allowing one to judge on the SC state of a sample.

In case of the magnetic moment absence in a sample, the dissipation and frequency of oscillations do not depend on an external magnetic field. The presence of pinned magnetic dipoles generates a nonzero magnetic moment M in a sample even at room temperature. The interaction between M and H generates the moment $\tau = M\ H \sin\alpha$, where $\alpha$ is the angle between M and H. This moment $\tau$ affects both the immobile and oscillating systems, making the dissipation and frequency of oscillations depending on the external magnetic field, especially with the presence of vortices in the mixed ($H > H_{c1}$) state of separate areas of HTSC under study.

As was shown in work [13], for the superconductors in the mixed state, the interaction between pinned and free Abrikosov vortices plays an important role in the dynamic oscillating processes affecting both the frequency $\omega$ and the dissipation $\delta$ of the energy of oscillations. It is well known that the pinning force also depends strongly on the temperature, for example, it tends to zero at the approaching $T_c$. At the same time, the concentration of free vortices increases, and the value of $\omega$ accordingly sharply decreases.

In Figure 1 the results of $T_c$ measurements by three methods are presented for the starting superconducting sample Bi-Pb-Sr-Ca-Cu-O (2223). As is seen, all these methods give the same $T_c$=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 the 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. As is seen from the figure 2, the critical temperature of the superconducting transition after the shock wave effect increases as compared with the starting sample on 8 degrees, from $T_c$=107 K to $T_c$=115 K.

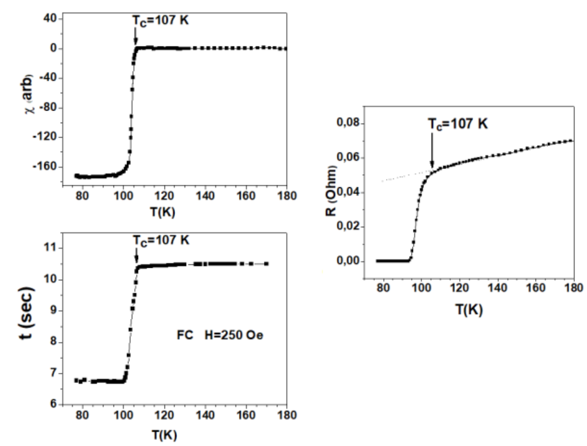


**Figure 1 The Temperature Dependence Of Electric Resistance R, Magnetic Susceptibility χ And Oscillation Period T Of The Initial Superconducting Sample $Bi_{1.7}pb_{0.3}sr_2ca_2cu_3o_{10-\delta}$ (2223) Suspended By A Thin Elastic Thread And Making Axial-Torsional Oscillations In A Transverse Magnetic Field.**

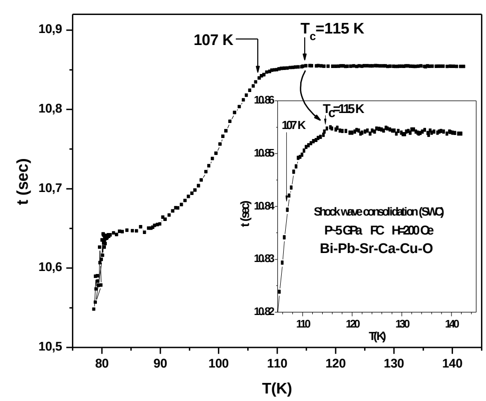


**Figure 2 Dependence Of Period T On The Temperature T Of The Superconducting Sample Fabricated At P ~ 5 Gpa, Then Suspended By A Thin Elastic Thread And Making Axial-Torsional Oscillations In A Transverse Magnetic Field.**

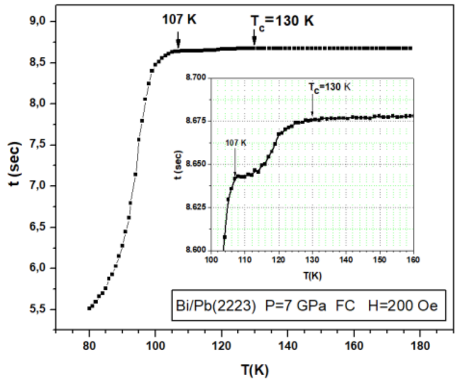


**Figure 3 Dependence Of Period T On Temperature T Of The Superconducting Sample Fabricated At P ~ 7 Gpa, Then Suspended By A Thin Elastic Thread And Making Axial-Torsional Oscillations In A Transverse Magnetic Field.**

In the Figure 3, similar results for P≈7 GPa are presented. In this case, the critical temperature further increases and turns out to be of the order T=130 K, i.e., the increase of $T_c$ constitutes a value of the order of 23 degrees.

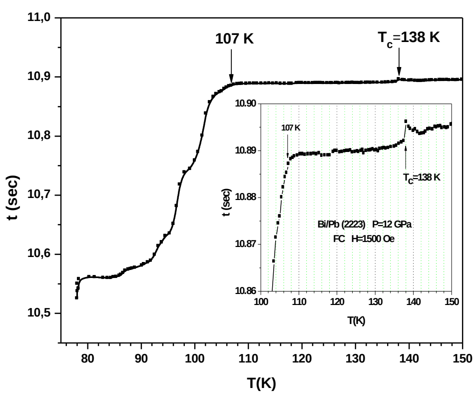


**Figure 4 Dependence Of Period T On The Temperature T Of The Superconducting Sample Fabricated At P ~ 12 Gpa, Then Suspended By A Thin Elastic Thread And Making Axial-Torsional Oscillations In A Transverse Magnetic Field.**

In the Figure 4, similar results for pressures of the order of P≈12 GP are presented. In this case, $T_c$ increases by an additional 8 degrees and constitutes the value of $T_c$=138 K.

The surface photos of polished samples showed no contaminations and a reasonable consolidation, i.e., good densification results [4].

The figures show 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 $Bi_{23}Sr_2CaCu_2O_{8+\delta}$ was also reported in [14].

It was also 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. For $T_c$ control of the fabricated samples, the conventional magnetization and resistivity measurements were used. But by these methods, the HTSC precursors with T> $T_c$ were not observed.

### *2.2 Superconducting Precursors in Bi-Pb-Sr-Ca-Cu-O Compositions Fabricated by SFAQ-T Technology*

In works [8,9], precursors were synthesized using SFAQ-T technology quenching the melt obtained by heating with solar radiation at low temperatures.

The studies were accompanied by the testing of samples by electrical resistivity R (the 4-contact method) and the magnetic susceptibility χ measurements. The characters of the χ(T) and t(T) dependencies coincide, Figure 1, as shown in [4] 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.

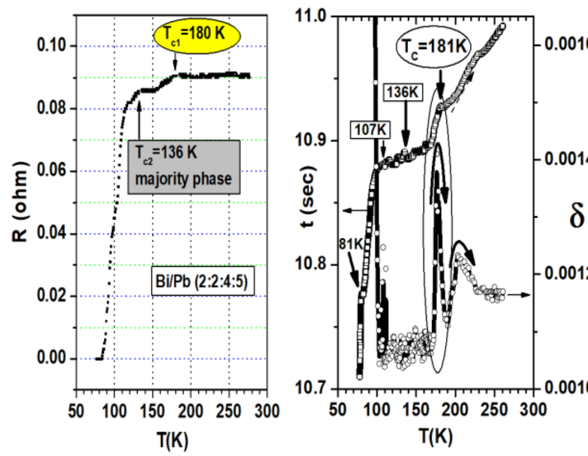


**Figure 5 Temperature Dependences Of The Electrical Resistivity R, As Well As The Oscillation Period T And The Logarithmic Decrement Δ Of Bi/Pb (2:2:4:5) Sample, Obtained From Sfaq-T Precursors And Measured After The Fc (Field Cool) Procedure At H = 150 Mt.**

In Figure 5, the typical temperature dependences of the period t and the logarithmic decrement of damping δ of the Bi/Pb sample (2:2:4:5) from [15] are presented, as well as the electrical resistivity R. All measurements were performed at increasing temperatures from T = 77 K to T = 300 K. As can be seen in Figure. 5, the critical temperature $T_c$ ≈180 K clearly manifests itself in the dependences of both R(T) and t(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 in this case in one of phases (region, crystallite, grain) with $T_c$ ≈180 K. As the temperature rises, other attenuation peaks are also observed on the δ(H) dependence, indicating the presence of the other higher-temperature superconducting phases in this multiphase sample.

Critical temperature with $T_c$= 201 K was subsequently detected [9] 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 201 K is shown in Figure 6b.

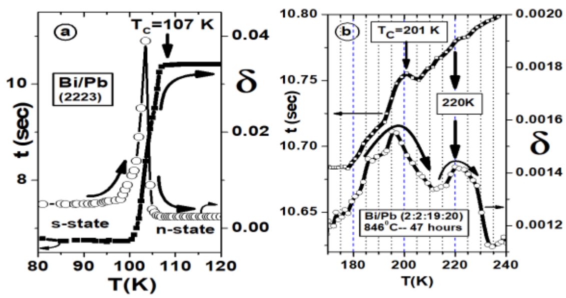

**Figure 6 Temperature Dependences Of The Period Of Oscillations Of T And Δ-Logarithmic Damping Decrement: A) For Monophase Bismuth Cuptare (2223), Obtained By Solid Phase Synthesis [4]; B) A Fragment For Multiphase Bi/Pb (221920), Derived From Sfaq-T Precursors. The Measurements Were Carried Out After Fc (Field Cool) Procedure At The Field H = 150 Mt.**

It should be noted that, as in the case of the multiphase Bi/Pb sample (2:2:4:5) shown in Figure 5 and for the Bi/Pb sample (2:2:19:20) in Figure 6b, after the increase of temperature, a second attenuation peak is also observed on the δ(H) dependence, indicating the presence of other HTSC phases in these multiphase samples.

When studying multiphase bismuth cuprates [15], it was established that the character of the curves t(T) and δ(T) varies with the time of exposure of the sample at T = 77 K in a magnetic field, after abrupt FC cooling. Figure 7 shows the results of measurements on a Bi/Pb sample (2:2:19:20) after holding it in liquid nitrogen at H = 150 mT for 7 hours (n-state). Attention is drawn to the fact that the critical phase temperatures at T = 100, 128, 154, 172, 217, 242, and 261 K are most clearly manifested in peaks due to the attenuation, although the 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 $T_c$.

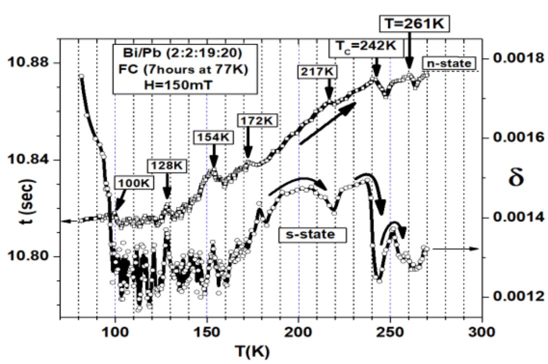

**Figure 7 Temperature Dependence Of The Oscillation Period T And The Logarithmic Damping Decrement Δ For Multiphase Bi/Pb (221920), Obtained From Sfaq-T Precursors And Annealing (846°c - 47 H). The Results Of Measurements When Sample Was Held During 7 Hours In Liquid Nitrogen In The Magnetic Field H = 150 Mt (N-State) As Compared With As-Prepared Sample (S-State).**

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

Previous measurements of pinning and dissipation processes were carried out by the original low-frequency vibrating torsion mechanical magnetometry method to study the torsion oscillations of samples in an applied magnetic field using the automated multipurpose device [10] and standard methods of magnetic and electric measurements. It was shown that samples obtained using the SFAQ-T technology were multiphase, containing phases with the critical temperatures $T_c$ more than 200 K. However, the concentration of new HTSC phases was so small that for more precision assessments it was necessary to find out an alternative more sensitive method. One of such methods could be the comparatively higher-frequency vibration reed (VR) magnetometry method for the first time developed by our group and independently in [12]. As the frequency and dissipation of VR could be measured with a high precision, the VR method exceeds in sensitivity a conventional ac-susceptometry method. Using the VR method, one could study the elastic coupling between the Abrikosov vortex lattice and the crystal lattice even in micron-sized HTSC grains in the normal matrix. The measurements of VR resonance frequency and dissipation dependences on the outer magnetic field strength H could be used for the precision investigation of the first critical magnetic field $H_{c1}$ temperature dependence without the introduction of free parameters, along with the energy dissipation character caused by the motion of the Abrikosov vortex lattice.

In [16] the example of the application of the VR method for the investigation of two-phase Bi-Ca-Sr-Cu-O superconducting ceramics for the precision assessment of their bulk critical temperatures $T_c$ was presented. The VR method was used for the first time in [11] to determine critical temperatures of superconducting precursors above bulk $T_c$. It was shown that this method had the sensitivity to superconducting diamagnetism sufficient to reveal new superconducting precursor phases above bulk $T_c$.

The electronic part of the setup contains an acoustic spectrometer operating at frequency about 1 kHz and instruments for powering a permanent magnet 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 in the mode of self-excitation of samples at their natural resonant frequencies. The electrode, located in the immediate vicinity of a sample, makes up with it the capacitance included in the oscillating circuit of the high-frequency generator, and serves simultaneously to excite and detect oscillations of a sample. Measurements of the resonanant frequencies $f_r$ of the sample oscillations make it possible to determine the elastic modulus E according to the relation:

$$f_r = k\frac{d}{L^2}\sqrt{\frac{E}{\rho}} \quad (1)$$

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 [12], 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 $\Delta f$(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 AV 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 the determination of the lower critical magnetic field Hc1 value. Figure 8 shows the dependence of $f^2$(H) of the sample (2267) taken at T=88 K, while its superconducting transition temperature is $T_c$ = 97 K.

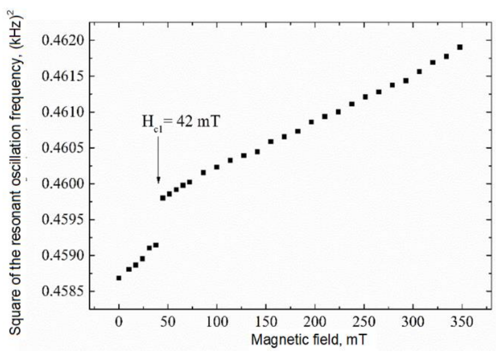


**Figure 8 Field Dependence Of The Square Of The Natural Frequency Of The Sample (2267).**

The anomaly $f^2$(H) at 42 mT shows the moment of penetration of the magnetic field vortices into the sample at $H_{c1}$. An increase in $f^2$ corresponds to the increase of the number of AVs with the increase in H. From the slope of this curve, one can judge the pinning force in this particular sample. In this work, the temperature dependences of the square of the natural frequency $f^2$(H) of an HTSC sample oscillating in a magnetic field were used to obtain information on the phase composition of the SC precursors above $T_c$. When a superconducting VR is subjected to the applied field and temperature variations, a step-like increase in the resonant frequency $\Delta f = f - f_o$ as compared to its normal state value $f_o$ is observed near or below the upper critical magnetic field $H_{c2}$(T), when flux lines are rigidly pinned to VR. This is due to the diamagnetic surface currents flowing in the superconductor and producing diamagnetic restoring force proportional to the **M** x **H** torque.

This feature when applied above $T_c$ completely removes the normal-state contributions allowing one to trace the diamagnetic signal above $T_c$ with a great precision. Prior to the measurements, the samples were cooled to the nitrogen temperature in an external magnetic field, after which the temperature dependencies of $f^2$ were taken during a slow, ≈ 1 K/min, heating. 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. Figure 9 shows the $f^2$(T) dependence of the niobium substrate without the HTSC sample, taken in the 300 mT external magnetic field.

It is seen that the $f^2$(T) curve, in the temperature range from the liquid nitrogen temperature 77 K to 170 K, has a uniform slope and does not contain any features. Figure 10 shows the $f^2$(T) dependence of (2267) sample, taken in an external magnetic field of 300 mT. The curve contains a single feature at T = 97 K. Such features on the $f^2$(T) dependence are typical for phase transition points, so as the 97 K point is the sample transition temperature from the normal to superconducting state. There are no other features on the curve. This means that the sample (2267) is monophase. Another picture is observed on the $f^2$(T) curve of the sample (2-2-19-20), shown in Figure 11. On the dependencies, taken at a magnetic field of 300 mT during the heating process, four features are observed. This means that in the (2-2-19-20) sample, along with the main superconducting phase with the transition temperature of 104 K, there are inclusions of other superconducting phases with higher transition temperatures: 118, 127, and 151 K.

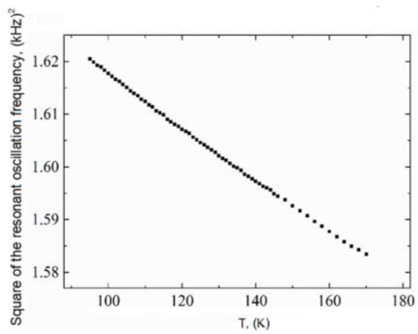


**Figure 9 Temperature Dependence Of $f^2$ Of The Niobium Substrate In Magnetic Field Of 300 mT.**

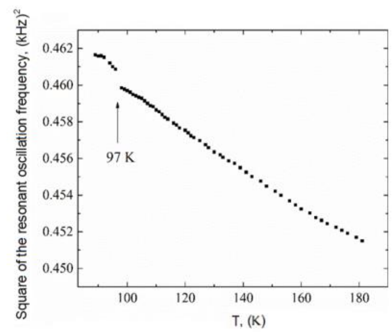


**Figure 10 Temperature Dependence Of $f^2$ Of The Monophase Sample (2267) In The Magnetic Field Of 300 mT.**

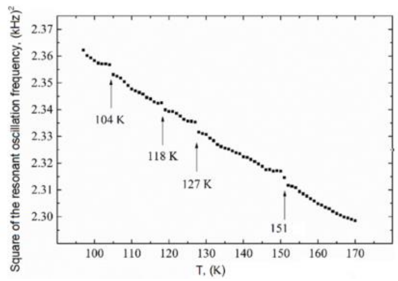


**Figure 11 Temperature Dependence Of $f^2$ Of The Multiphase Sample (2-2-19-20) In The Magnetic Field Of 300 mT.**

## CONCLUSION

1. The possibility of increasing $T_c$ in HTSC samples of 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 as follows:
   - the high-density materials were made from Bi-Pb-Sr-Ca-Cu-O superconducting system;
   - after the action of the explosive wave the superconductivity was retained;
   - after the explosion, a pronounced texture was formed indicating the creation of efficient pinning centers and thus, the increase of the current-carrying ability of the obtained material;
   - the critical temperature of potential superconducting precursor $T_c$ of transition to 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 31 K increase of $T_c$ on the 12 GPa case.
2. In the torsional low-frequency dynamic experiments in the course of investigation of the magnetic properties of multiphase cuprate superconductors $Bi_{1,7}Pb_{0,3}Sr_2Ca_{n-1}Cu_nO_y$ (n=2-30), synthesized using solar energy and superfast quenching of the melt (SFAQ-T technology), the precursor phases with of $T_c$ 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 infer the existence of the high-temperature superconducting precursor phases.
3. The potential possibilities of the vibrating reed method magnetometry for the evaluation of $T_c$ of superconducting precursors in the multiphase HTSC Bi-Pb-Sr-Cu-O system fabricated by the SFAQ-T technology were also investigated for the first time. It was shown that this method has the sensitivity to superconducting diamagnetism making it possible to reveal new superconducting precursor phases above bulk $T_c$ in these samples.

## CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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