Effect of phenidone adsorption on the superconducting parameters of ceramics Bi-Pb-Sr-Ca-Cu-O

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Abstract

A treatment of the $Bi_{1.8}Pb_{0.3}Sr_{3-x}Ca_{1+x}Cu_3O_z$ ceramics with acetone solution of phenidone at room temperature during 50 days resulted in: (1) a 30-40 % increase in critical current for the ceramics with an optimal x, (2) a high-temperature superconducting phase (with T_c=105 K) appears in the strontium rich ceramics which was originally almost nonsuperconducting above 77.4 K.

Key words: bismuth HTSC ceramics; adsorption; modification

1. Introduction

Organic molecules of hydroquinone and phenidone adsorbed at room temperature can modify the superconducting properties of yttrium HTSC ceramics [1]. This effect shows itself as an increase in T_c and an increase in the fraction of intergranular contacts involved in the transport current conductivity up to the values typical of optimal chemical compositions of the ceramics. However, the adsorbed molecules of hydroquinone and phenidone interact with labile oxygen of the superconductor to yield water molecules, which provides a severe degradation of the superconducting phase. It is anticipated that a similar treatment of the bismuth HTSC ceramics with organic reducing agents would not result in the degradation of the superconducting properties of Bi-based ceramics because it is more stable to water action [2]. The goal of the present work was to study the effect of phenidone (1-phenyl-3-pyrazoline) adsorption on the $Bi_{1.8}Pb_{0.3}Sr_{3-x}Ca_{1+x}Cu_3O_z$ ceramics with different Sr/Ca ratio.

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2. Experimental

HTSC ceramics $Bi_{1.8}Pb_{0.3}Sr_{3-x}Ca_{1+x}Cu_3O_z$ used in our experiments was synthesized by the standard technology and was ground, the size of the ceramics particles was 1-5 μm. The samples were treated with 0.1 M solution of phenidone (99.9 %) in pure acetone (99.99 %) into sealed glass ampoules. *In situ* studies of superconducting properties of our samples were performed using ac magnetometer. The dependence of the real part of the magnetic susceptibility on the external magnetic field was registered during specified time intervals. Temperature of the superconducting transition of the samples was measured before and after the experiments when the samples were taken from the ampoules.

3. Results and discussion

Fig.1 present the parameters of superconductivity for the ceramics studied. One can see that the relation between the concentration of calcium and strontium (index x) strongly affects the superconducting

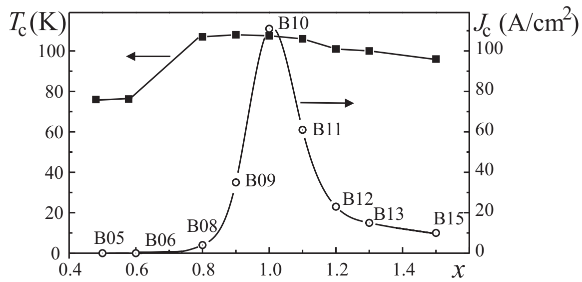

Fig. 1. Transition temperature T_c and critical current density J_c (at 77.4 K) of the initial $Bi_{1.8}Pb_{0.3}Sr_{3-x}Ca_{1+x}Cu_3O_z$ sample with various x.

properties of the initial ceramics. For samples B05 and B06 (rich in strontium), the superconducting transition temperature is near to 78 K, and the density of transport critical current is less than 1 A/cm^2. When the samples are treated with phenidone for 50 days, their superconducting properties change. For B05 and B06, this change is especially pronounced. Thus the superconduction transition temperature increased to 105 K, which is characteristic of the bismuth HTSC ceramics with an optimal chemical composition.

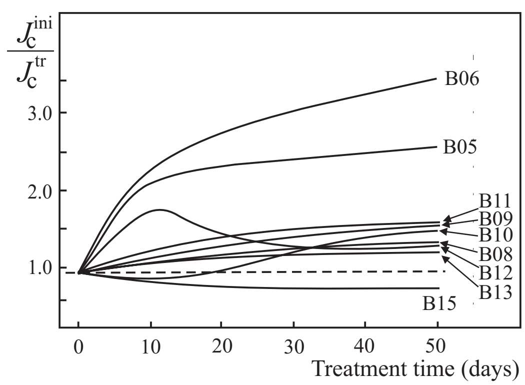

Fig. 2. Relative changes of the critical carrent density (at 77.4 K) of the $Bi_{1.8}Pb_{0.3}Sr_{3-x}Ca_{1+x}Cu_3O_z$ ceramics treated with phenidone vs. treatment time.).

Fig. 2 shows the relative changes of the critical current density in the field of 10 mT and at 77.4 K versus treatment time. As follows from the figure, J_c for all samples (excepting sample B15) increases with increasing treatment time. For samples B05 and B06, this increase is especially high. A significant increase in the fraction of superconducting phase in the above samples is responsible for this phenomenon. For the samples with optimal calcium and strontium concentrations (samples B09, B10, and B11), critical current also increases with treatment time. Compared to samples B05 and B06, this increase is associated with the strengthening of contacts, because the fraction of the superconducting phase in the samples changes insignificantly with treatment time. When the ratio between calcium and strontium is not optimal (samples B08, B12, and B13), critical current slightly increases due to an increase in the superconducting phase.

To elucidate the mechanism of effect of phenidone molecules on the superconducting properties of bismuth ceramics, we have performed XRD and IR spectroscopy investigations. XRD patterns of treated samples indicate an increase in the size of an elemental crystal cell resulting from the removal of highly labile oxygen intercalated between -BiO- and -OBi- layers [3]. IR spectra of treated ceramics showed that after adsorption of phenidone on the ceramics surface, the individual lines of phenidone disappear and the lines of oxypyrazole (oxidized phenidone) appear. Thus, the adsorption of phenidone on the surface of the bismuth ceramics is accompanied by chemical reaction, i.e. oxidation of phenidone to oxypyrazole by the labile lattice oxygen. Hence, concentration of oxygen in the ceramics lattice decreases that results in an optimization of oxygen content and an increase of T_c for the samples B05 and B06.

4. Conclusion

Treatment of $Bi_{1.8}Pb_{0.3}Sr_{3-x}Ca_{1+x}Cu_3O_z$ ceramics with the solution of phenidone in acetone results in a increase in critical current for the ceramics. The samples with high strontium/calcium ratio initially being almost nonsuperconducting becomes superconducting with T_c=105 K after the treatment with phenidone. This modification is associated with chemical reaction between the adsorbed organic molecules and the labile lattice oxygen of the ceramics. Due to this interaction the optimal oxygen stoichiometry of the ceramics is recovered and high-T_c phase arises.

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