Effect of adsorbed molecules of phenidone and hydroquinone on the critical superconducting parameters of ceramics Y-Ba-Cu-O

Lev. L. Makarshin, Dmitry V. Andreev [1], Natalia A. Golikova, Valentin N. Parmon

Boreskov Institute of Catalysis, pr. acad. Lavrentieva 5, 630090 Novosibirsk, Russia

Abstract

Hydroquinone and phenidone react with Y-Ba-Cu-O ceramics and change its critical parameters: T_c increases from 89.5 to 93 K; fraction of the intergranular contacts and fraction of the superconducting phase increases. These effects are associated with the surface chemical reactions which modify the superconducting granules of the ceramics.

Key words: transition temperature increase; HTSC modification

1. Introduction

A mild modification of HTSC materials with the use of organic compounds makes it possible to change superconducting properties in a controlled fashion. The effect of adsorption of organic compounds on superconducting properties was first studied using superconducting metallic films. It was shown [1] that the adsorption of 3,4,7,8-tetramethyl-1,10-phenanthroline on a thin vanadium film increases the T_c by 0.09 K. It was suggested that this effect is associated with electron-donor properties of the adsorbed molecule. The effect of organic donor-acceptor electron transport systems on the $YBa_2Cu_3O_{7-x}$ powder [2] results in its partial etching whereas its phase composition does not practically change. Because of the etching, labile subsurface oxygen appears to be removed and more structured crystalline layers are displayed. The possible influence of organic compounds on the properties of HTSC materials is overviewed in ref. [3].

The present work is aimed at studying the effect of adsorbed organic molecules with a high reducing ability - hydroquinone (p-dihydroxybenzene) and phenidone - (1-phenyl-3-pyrazoline) on the superconducting properties of ceramics $YBa_2Cu_3O_{7-x}$.

2. Experimental

Ceramics $YBa_2Cu_3O_{7-x}$ was synthesized by the standard ceramics method. The bulk samples were ground and sieved to obtain a fraction with the particles size smaller 60 μm. According to the XRD analysis, the samples contain one orthorhombic phase (1-2-3). We used hydroquinone (99 %) and phenidone (99.9 %). The $YBa_2Cu_3O_{7-x}$ powder (120 mg) was treated in sealed glass ampoules with a 10^{-3}M solution of hydroquinone or phenidone in benzene at room temperature in benzene (99.99 %) preliminary dried with a zeolite. After the treatment during a definite period, the powder was dried. The tests showed that the superconducting properties of the ceramics maintained after its soaking in pure benzene.

Superconducting properties of the ceramics were measured with a specially designed ac magnetometer. The magnetometer allows to measure temperature dependencies of the real part of the ac magnetic susceptibility at various values of external magnetic field. The parameters of superconductivity (at 77.4 K, except T_c) were calculated using the Kim's model of critical state [4].

[1] Corresponding author. E-mail: andreev@catalysis.nsk.su

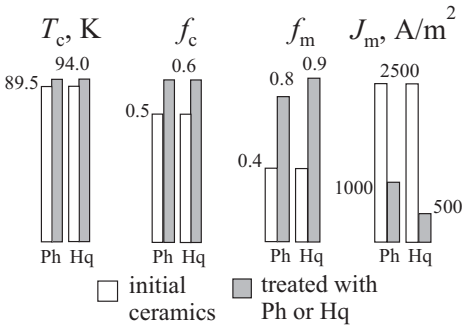

Fig. 1. Superconducting parameters for $YBa_2Cu_3O_{7-x}$ ceramics before and after the treatment with phenidone (Ph) and hydroquinone (Hq) (10^{-3}M solution in benzene, 25^0C, 144 h).

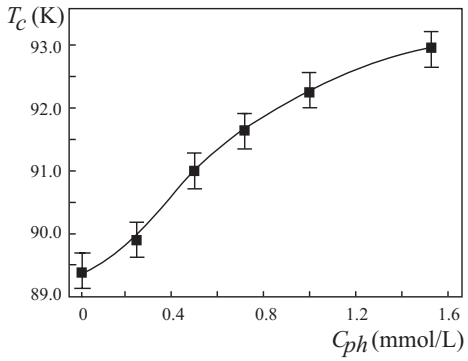

Fig. 2. T_c of $YBa_2Cu_3O_{7-x}$ ceramics vs. phenidone concentration in benzene after the treatment (25^0C, 2.5 h).

3. Results and discussion

Fig.1 show a change of the superconducting parameters resulting from the treatment of $YBa_2Cu_3O_{7-x}$ with hydroquinone and phenidone. There are an increase of both critical temperature T_c and the fraction of intergranular contacts f_m, participating in the superconducting transport current conductivity. The fraction of superconducting phase f_c also raised. The transport critical current density J_m decreased by a factor of 2.5 and 5.0 for the samples treated with phenidone and hydroquinone, respectively.

The treatment of ceramics with hydroquinone and phenidone is most likely accompanied by a chemical reaction on the surface of the ceramics granules. A number of additional defects form in the granules, providing a formation of new intergranular contacts increasing of f_m. XRD of the initial and the treated ceramics indicate that the region of coherent scattering was decreased after the treatment that proves the increased defectiveness of the treated ceramics .

Fig. 2 shows the curve of T_c for the treated ceramics $YBa_2Cu_3O_{7-x}$ vs. the concentration of phenidone in benzene. As the C_{ph} increases, T_c increases too. Such behavior may be associated with the fact that hydroquinone and phenidone adsorption on the $YBa_2Cu_3O_{7-x}$ surface results in a change in the valence state of the lattice oxygen and copper ions.

It is well known that molecular oxygen easily oxidizes hydroquinone into quinone and phenidone to oxypyrazole to yield hydrogen peroxide [5]. On the ceramics surface labile oxygen can oxidize the adsorbed hydroquinone or phenidone, the formed hydrogen peroxide can oxidize Cu^{2+} to Cu^{3+}:

$$2Cu^{2+} + H_2O_2 = 2Cu^{3+} + 2OH^- . \quad (1)$$

A thermochemical modeling of systems Y-Ba-Cu-O [6] showed that T_c depends on the concentration of Cu^{3+} (in at.%) in the ceramics lattice: $T_c = 45.32 + 1.433[Cu^{3+}]$. That conforms to the increase of T_c observed after the ceramics treatment with hydroquinone or phenidone (Fig. 2). It should be noted that reaction (1) involves formation of hydroxyl ions which strongly degrade the superconducting properties of $YBa_2Cu_3O_{7-x}$ [3]. A significant reduction of J_m of the samples treated with hydroquinone and phenidone seems to be also associated with this effect.

4. Conclusion

Adsorption of hydroquinone and phenidone modifies the superconducting properties of ceramics $YBa_2Cu_3O_{7-x}$. This modification is associated with the reduction of the labile lattice oxygen by the organic molecules and formation of the Cu^{3+} cations in the ceramics lattice.

Acknowledgements

We thank The Program "Universities of Russia (UR.06.01.025)" and The Program "Leading Scientific Schools (00-15-97446)" for financial support.

References

[1] H.M. McConnell, B.M. Hoffman, D.D.Thomas, Proc. Natl. Acad. Sci., U.S.A. **54** (1965) 371.

[2] G.A. Nifontova, N.V. Kiryakov, Y.G. Morozov, V.I. Ponomarev, I.P. Lavrentiev, Superconductivity: physics, chemistry, technology **5** (1992) 2375 (Russ).

[3] L.L. Makarshin, D.V. Andreev, V.N. Parmon, Russian Chemical Reviews **69(4)** (2000) 279.

[4] D.X. Chen, J. Nogues, K.V. Rao, Cryogenics **29** (1989) 800.

[5] The theory of the photographic process. 3rd edition, edited by T.H.James. (The Macmillan Company, New York, 1966).

[6] G.K. Moiseev, N.A. Vatolin, Zh. Fiz. Chim. **72** (1998) 353 (Russ).