Modification of structure and super conducting properties of Y-Ba-Cu-O films by laser emission

V. Makara, V. Pasetchny, O. Rudenko, G. Vesna

► To cite this version:

V. Makara, V. Pasetchny, O. Rudenko, G. Vesna. Modification of structure and super conducting properties of Y-Ba-Cu-O films by laser emission. Journal de Physique IV Proceedings, 1994, 04 (C4), pp.C4-163-C4-166. 10.1051/jp4:1994436 . jpa-00252699

HAL Id: jpa-00252699

<https://hal.science/jpa-00252699>

Submitted on 1 Jan 1994

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Modification of structure and super conducting properties of Y-Ba-Cu-O films by laser emission

V.A. MAKARA, V.O. PASECHNY, O.V. RUDENKO and G.V. VESNA

Taras Shevchenko University, Department of Physics, Volodimirska st. 64, 252017 Kiev, Ukraine

ABSTRACT

There was investigated the change of Y-Ba-Cu-O structure of monocrystalline films and polycrystalline facings under the effect of laser radiation (1,06 μm , 4 ms). The obtained results indicate the threshold character of changes of their superconductivity properties. As certain radiation energies it is possible to observe improvement of superconductivity properties.

INTRODUCTION

Laser treatment of materials acquired wide application of the method allowing to modify essentially the structure of materials, what may not be achieved through other methods. Thus, it was of interest to seek for the ways of improving superconductivity properties of high-temperature superconductivity materials through laser treatment.

WORK'S AIM

Modification of the superconducting properties and structure of the monocrystalline and polycrystalline Y-Ba-Cu-O films by the laser treatment is the objective of this work.

EXPERIMENTAL PROCEDURE

Monocrystalline films of thickness $h=0,2-0,5 \mu\text{m}$ were produced by magnetron sputtering of ceramic target on Mg(100) substrates.

Polycrystalline facing ($h=20-200 \mu\text{m}$) were produced by flame spraying on stainless-steel substrates and also on copper substrates with ZrO_2 buffer layer.

Samples were irradiated by a YAG Laser (1,06 μm) operation in a free-running mode with a pulse duration of ~ 4 ms.

RESULTS AND DISCUSSION

X-Ray structural analysis of monocrystalline films showed that they were epitaxial

ones, thus the (001) plane was parallel to the (100) MgO substrate surface and they were in orthorhombic phase of the crystal lattice parameter $c = 11,70$ Å. Polycrystalline had crystal lattice parameters $a = 3,84$ Å, $b = 3,88$ Å, $c = 11,65$ Å.

Figures 1 and 2 present the typical plots $R(T)$ for samples of the monocrystalline film and the polycrystalline facing.

The obtained experimental evidence threshold character of the laser modification of monocrystalline films results in improvement of superconducting properties of the Y-Ba-Cu-O films.

The irradiance by $E = 11 \pm 1$ J/cm² for polycrystalline and $E = 14 \pm 1$ J/cm² for of their electrical parameters. The increase of the critical temperature in the beginning of superconducting transition from $T_c = 77-85$ K to $T_c = 82-92$ K is observed. The critical current increases 1,5-2,0 times and the effective resistance decreases 2-5 times. The superconducting properties disappear in the energies $E > 15$ J/cm².

The X-Ray diffractogrammes of monocrystalline films (Fig.3) indicate the division of L_1 and L_2 dublet and their narrowing at the remote angles and the threshold value of E .

It is necessary to note as the monocrystalline films have more smooth surfaces and better reflect the falling energy, what causes the shift of their threshold value to the area of higher energies, unlike the polycrystalline.

Microstructure studies of the films show that monocrystalline films have crystal twin structure of average length of twins about 15000 Å. Laser treatment of the films up to $E \approx 30$ J/cm² does not change the dimensions of the twins, but it provokes their cracking and sublimation ($E \geq 17$ J/cm²).

Improvement of the superconducting properties of films and may be determined by different factors: relaxation of internal tension; modification of weak intergranular bonds; dissolving of the sample pores oxygen; evolution of the film structure defects and others.

Further increase of laser irradiation energy over the threshold values results in a rapid degradation of superconducting properties of films. This involves a progressive transformation of orthorhombic superconducting phase into tetragonal nonsuperconducting one (Fig.4). For monocrystalline films $c = 11,82$ Å, and for polycrystalline ones $a = b = 3,86$ Å, $c = 11,82$ Å. Firstly, increase of E -value results in broadening of lines and their shift towards smaller angles, and later to their division into two lines with parameters $c_1 = 11,71$ Å and $c_2 = 11,82$ Å.

In $E \approx 20$ J/cm² parameter c begins to increase oxygen begins to leave the lattice: the films probably are mixture of the metastable phases with different oxygen content (up to the appearance of tetragonal phase). When the energy E attains ~ 30 J/cm² the structure of the samples corresponds in general to tetragonal modification.

Thermal annealing of the samples in vacuum the air was to elucidate the nature of the laser treatment on the HTSC-materials. In vacuum $\sim 10^{-2}$ torr the samples were annealed at 400 °C during 15 min and cooled to the room temperature within ~ 4 min. Thermal annealing in the

Fig. 1. Resistivity - temperature relationship in the polycrystalline coverage: 1 - initial, 2 - 5 j/cm², 3 - 9 j/cm², 4 - 12 j/cm².

Fig. 2. Resistivity - temperature relationship in the monocrystalline film: 1 - initial, 2 - 12 j/cm², 3 - 14 j/cm², 4 - 15 j/cm².

Fig. 3. Fragments of the X-ray diffractograms of the reflections (0013) for the initial (a) and after laser annealing $E=13,5$ j/cm² (b) of the monocrystalline films.

Fig. 4. The lattice parameter $c(E)$ and $I_0/I_t(E)$ relationships in the monocrystalline film.

air was performed in following way: the samples were heated to 400 C of 20 degr/min speed, and then cooled to 20 C. The results are presented in the Table, which shows that thermal annealing of films in vacuum and the air provokes the same structural changes as laser annealing. Thus, both thermal and laser degradation of superconducting properties of Y-Ba-Cu-O films is due to changes of the state of oxygen sublattice, while the processes have a high rate of proceeding.

Table.

Variation of ϵ parameter of Y-Ba-Cu-O monocrystalline film after thermal annealing at 400 C

Sample	ϵ A
initial	11,70
annealed in the air	11,82
annealed under vacuum	11,84

CONCLUSIONS

The obtained experimental evidence threshold character of laser stimulated modification of HTSC-materials. The irradiance ($I=1,06 \mu\text{m}$, $t=4 \text{ ms}$) by energy $E \simeq 11 \pm 1 \text{ j/cm}^2$ for polycrystalline coverage and $E \simeq 14 \pm 1 \text{ j/cm}^2$ for monocrystalline films improves their electrical parameteres. In $E \geq 15 \text{ j/cm}^2$ the loss of superconducting properties results in progressive transformation of orthorhombic superconducting phase into tetragonal nonsuperconducting one.