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THE STABILIZATION OF HIGH-TEMPERATURE SUPERCONDUCTOR $Y_1Ba_2Cu_3O_{7-\delta}$ SURFACE

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A technique is suggested for stabilization of a high-temperature superconductor $Y_1Ba_2Cu_3O_{7-\delta}$ surface by means of a high-current pulsed electron beam (J = 12.5 ÷ 65 A/cm^2, E = 70 ÷ 200 keV, t = 300 ns, P = 0.001 Pa). The quality of the remelted surface film is characterized and first experimental results are discussed. It is shown that within 50 days after the electron beam processing, no dielectric film was developed at superconductor surface and superconductor characteristics did not change.

The investigation has been performed at the Scientifical-Methodical Division, JINR.

Стабилизация поверхности высокотемпературного сверхпроводника $Y_1Ba_2Cu_3O_{7-\delta}$

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Обсуждается метод стабилизации высокотемпературного сверхпроводника $Y_1Ba_2Cu_3O_{7-\delta}$ путем оплавления его поверхности импульсным сильноточным электронным пучком и приводятся первые экспериментальные результаты. В экспериментах использовался электронный пучок с параметрами: плотность тока 12,5÷ ÷65 А/см^2, кинетическая энергия электронов 70 ÷ 200 кэВ, длительность импульса тока пучка ~ 300 нс. Облучения проводились в вакуумных условиях при давлении остаточного газа P ~ 10^{-3} Па. Экспериментально показано, что в течение 50 суток после облучения на поверхности керамики $Y_1Ba_2Cu_3O_{7-\delta}$ отсутствует диэлектрическая пленка, а сверхпроводящие характеристики образца не ухудшаются.

Работа выполнена в Общеинститутском научно-методическом отделении ОИЯИ.

Y-Ba-Cu-O high-temperature ceramic superconductive materials are investigated in many laboratories throughout the world /1/. However, a certain progress has been achieved in fabricating superconductive high-temperature ceramics having stable superconductive characteristics. It must be mentioned that $Y_1Ba_2Cu_3O_{7-\delta}$ surface is degraded during storing superconductive samples in atmospheric environment. Apparently the surface degradation is caused by development of a surface dielectric layer composed of metal hydrooxides [2]. The existence of such a film may cause surface unstability problems.

In this rapid communication a method of the superconductor surface stabilization by means of a high current pulsed electron beam surface remelting is suggested, and our first experimental results are presented.

The surface thermoprocessing of many materials using concentrated pulses of high power beams (laser, electron, etc.) results in a stable protective layer [3].

In accordance with [3], for the case of pulsed electron beam used for the surface thermoprocessing it is necessary to have the beam power density higher than 10^6 W/cm^2 and the surface freezing velocity of material higher than 10^5 K/sec.

Analysing the model of the nanosecond electron beam interaction with material surface [4] it may be shown that the physical phenomena which are taking place during the electron pulse beam stabilization of the $Y_1Ba_2Cu_3O_{7-\delta}$ surface may be characterized as the adiabatic ones.

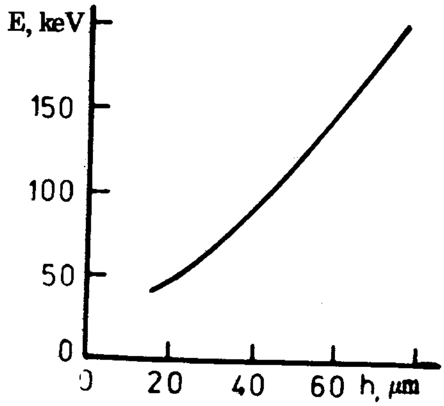
Due to lack of data in literature we have used approximative thermophysical data for our material and we have estimated the time constant of the e-beam remelted surface freezing as 10^{-4} sec. Thus the superconductor surface may be modified by our electron beam up to penetration depth of the electrons. (See fig. 1). The details of experiments with our electron beam source may be found in [5]. The ceramic samples which had been processed were placed behind e-beam source anode (cathode-anode-sample). The vacuum in the apparatus used was 10^{-3} Pa.

The dimensions of our experimental $Y_1Ba_2Cu_3O_{7-\delta}$ superconductive samples were 25x5x1 mm^3 and they were prepared in the Laboratory of Neutron Physics of the JINR at Dubna. The converted dielectric surface layer was mechanically removed directly prior to the electron beam processing. The surface of our experimental samples prior to and after the e-beam processing may be seen in SEM pictures (fig. 2). The picture of remelted surface is in fig. 2b. Using the results of [3] we have estimated the maximum surface temperature within the interval of 1500-2000° C during sample processing by means of e-beam.

The depth of modified layer estimated from SEM pictures (not shown) as 50-60 μm corresponds to fig. 1, penetration depth of electrons being 200 keV.

We have measured the electric resistance R of the samples immediately after the e-beam processing and 50 days after. The simple measu-

Fig. 1. Depedence of penetration dept h on energy of electrons E for $Y_1Ba_2Cu_3O_{7-\delta}$ material.



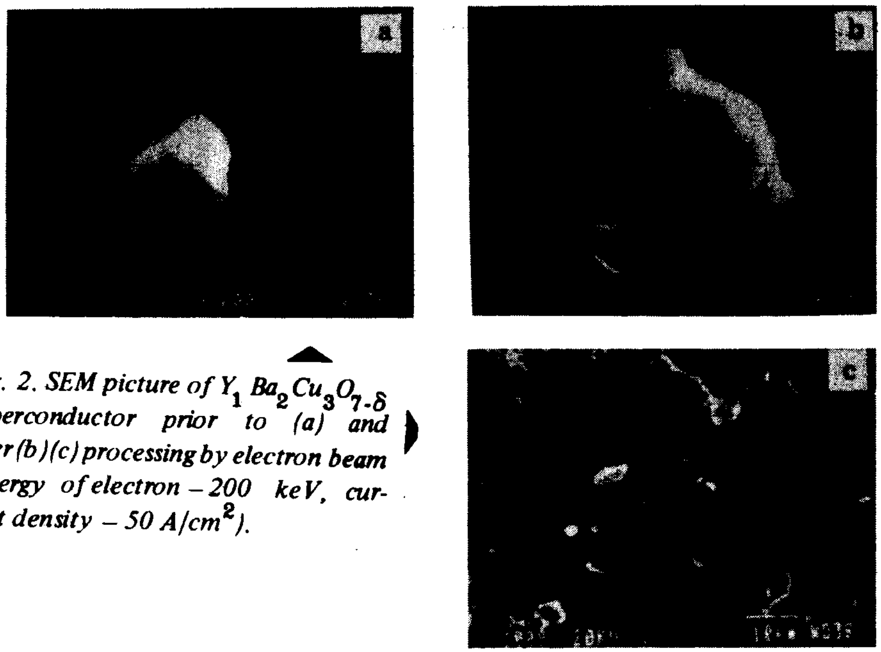
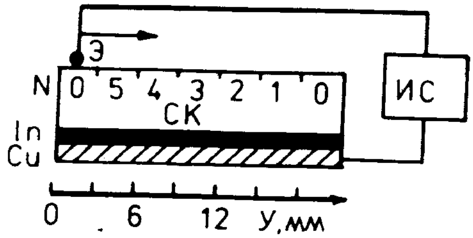


Fig. 2. SEM picture of $Y_1Ba_2Cu_3O_{7-\delta}$ superconductor prior to (a) and after (b)(c) processing by electron beam (energy of electron – 200 keV, current density – 50 A/cm^2).

Fig. 3. Measuring scheme of resistance R along the sample length: CK – superconducting ceramics, Э – electrode, N – number of electron pulses applied along length of sample, In – Indium layer, Cu – Cu electrode.



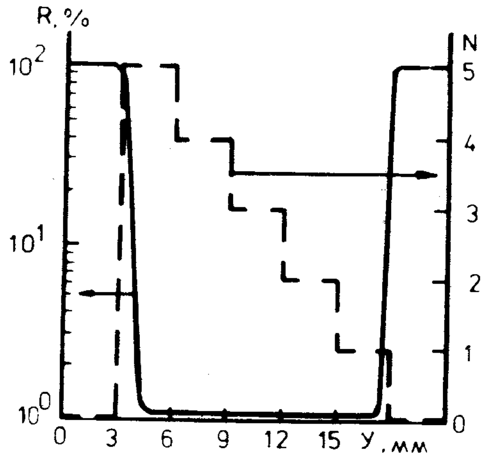


Fig. 4 The resistanse R along sample length Y dependence on number N of electron pulses applied (histogramm).

ring scheme is shown in fig. 3; and the results, in fig. 4. It may be seen that the resistance R of the surface processed is about two orders of magnitude lower than the resistance of unprocessed regions, R does not depend on the number of e-beam pulses applied subsequently—N, and R remains the same within 50 days after processing at least.

The analogic results were obtained for Nb_3Ge in[6] where characteristics of the surface did not depend on N too.

The evidence of a dielectric layer present on unprocessed $Y_1Ba_2Cu_3O_{7-\delta}$ surface was proved by impedance measuring. Originally all our samples had capacitive impedance but, after the e-beam processing the impedance was pure ohmic. The ohmic impedance was checked on the samples immediately after their dielectric film was removed mechanically but, it became capacitive few hours after again.

We believe that the high power pulsed electron beam stabilization of $Y_1Ba_2Cu_3O_{7-\delta}$ superconductive surface should be one of the new possibilities in the high temperature superconductivity technology.

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