FABRICATION OF THICK SUPERCONDUCTING FILMS BY DECANTATION

Julián Betancourt M.

Guillermo Franco A.

Departamento de Física.

Universidad Nacional de Colombia. Santafé de Bogotá, Colombia.

RESUMEN

Se ha encontrado un comportamiento superconductor en películas gruesas producidas por decantación. En el presente artículo se presenta el método experimental y los resultados obtenidos usando sustratos de cobre comercial.

ABSTRACT

We have found superconducting behavior in thick films fabricated by decantation. In this paper we present the experimental method and results obtained using commercial copper substrates.

INTRODUCTION

During the last two years we have carried out high Tc superconducting research on systems based on Ytrium and Bismuth, in bulk as well as in films (thin and thick). We have used different techniques: melting and quenching [1], thermal non-equilibrium [1] and decantation.

We have been developing this last technique to obtain thick superconducting films and the object of this paper is to describe it in order to contribute to the present research on superconductivity.

EXPERIMENTAL METHOD AND RESULTS

We have called decantation or precipitation our technique to fabricate thick films and it consists basically in the fine pulverization of bulk superconducting material (BSCCO, for example), followed by its suspension in a volatile liquid such as methanol and placing it inmediately in the recipient that contain the substrate material: a copper or bronze sheet, or a ceramic piece previously polished to assure a flat surface. Deposition time (1 to 10 minutes) depends on the desired film thickness. After this time, the substrate is retired from the suspension for a heat treatment, looking for interconnection of the deposited film as well as for adhesion of the film on the substrate. This treatment is determinant for the obtention of good thick superconducting films.

Figure 1 shows the resistance behavior of a superconducting sample with nominal weight composition of 50% Bi_2O_3, 30% SrO/Ca (molar relation 1/1), and 20% CuO, deposited on commercial copper. X-rays analysis indicates the existence of the n=1 and n=2 phases (see equation 1) [1,2].

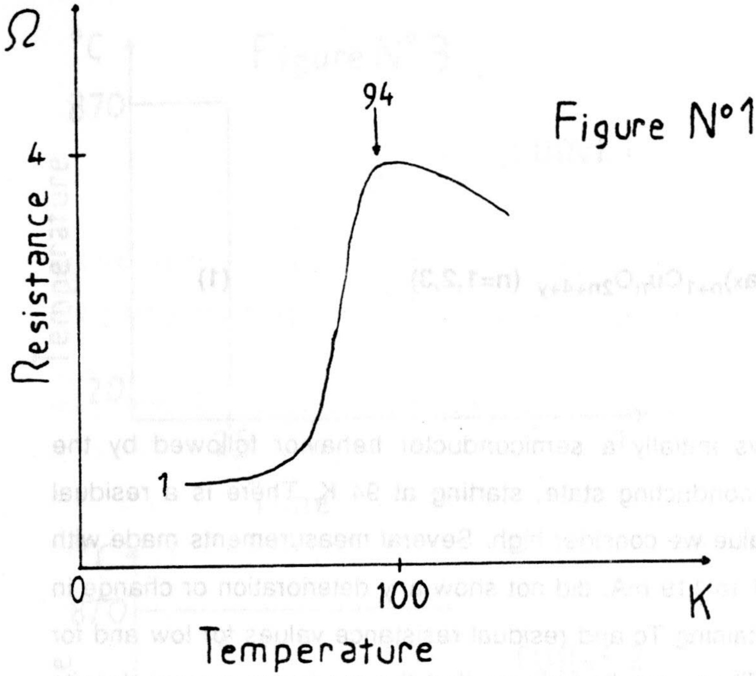

Figure 1. Curve 1 of Resistance vs. Temperature for a thick film of BSCCO deposited on copper. A semiconducting behavior is observed before transition.

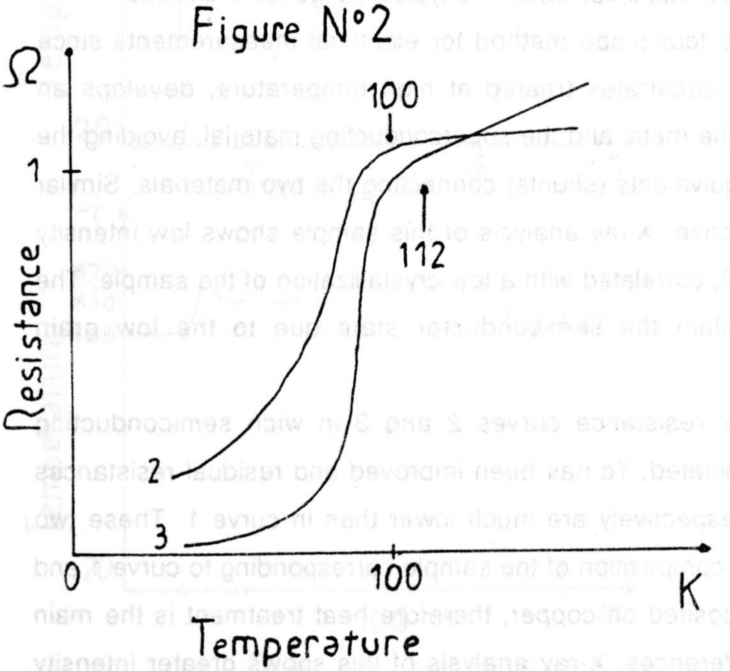

Figure 2. Curves 2 and 3 of Resistance vs. Temperature for a thick film of BSCCO deposited on copper. Semiconducting behavior is not observed due to thermal treatment.

$$Bi_{2.1}(Sr_{1-x}Ca_x)_{n+1}Cu_nO_{2n+4+y} \quad (n=1,2,3) \qquad (1)$$

The curve shows initially a semiconductor behavior followed by the transition to the superconducting state, starting at 94 K. There is a residual resistance of 1.75Ω, value we consider high. Several measurements made with currents ranging from 1 to 119 mA. did not show any deterioration or change in sample behavior, maintaining Tc and residual resistance values for low and for high currents as well. These results indicate that the maximum current density the film may support is higher than calculated for a current of 119 mA., which is of 10 $Acm.^{-2}$, being this a low value but within the typical range for thick films.

We have used the four-probe method for electrical measurements since the commercial copper substrates treated at high temperature, develops an insulating film between the metal and the superconducting material, avoiding the formation of resistive equivalents (shunts) connecting the two materials. Similar situation occurs with bronze. X-ray analysis of this sample shows low intensity peaks of the phase 2212, correlated with a low crystallization of the sample. The above results can explain the semiconductor state due to the low grain conectivity.

Figure 2 presents resistance curves 2 and 3 in wich semiconducting tendency has been eliminated, Tc has been improved and residual resistances of 0.125Ω and 0.05Ω respectively are much lower than in curve 1. These two samples have the same composition of the sample corresponding to curve 1 and all three have been deposited on copper, therefore heat treatment is the main responsible for their differences. X-ray analysis of this shows greater intensity

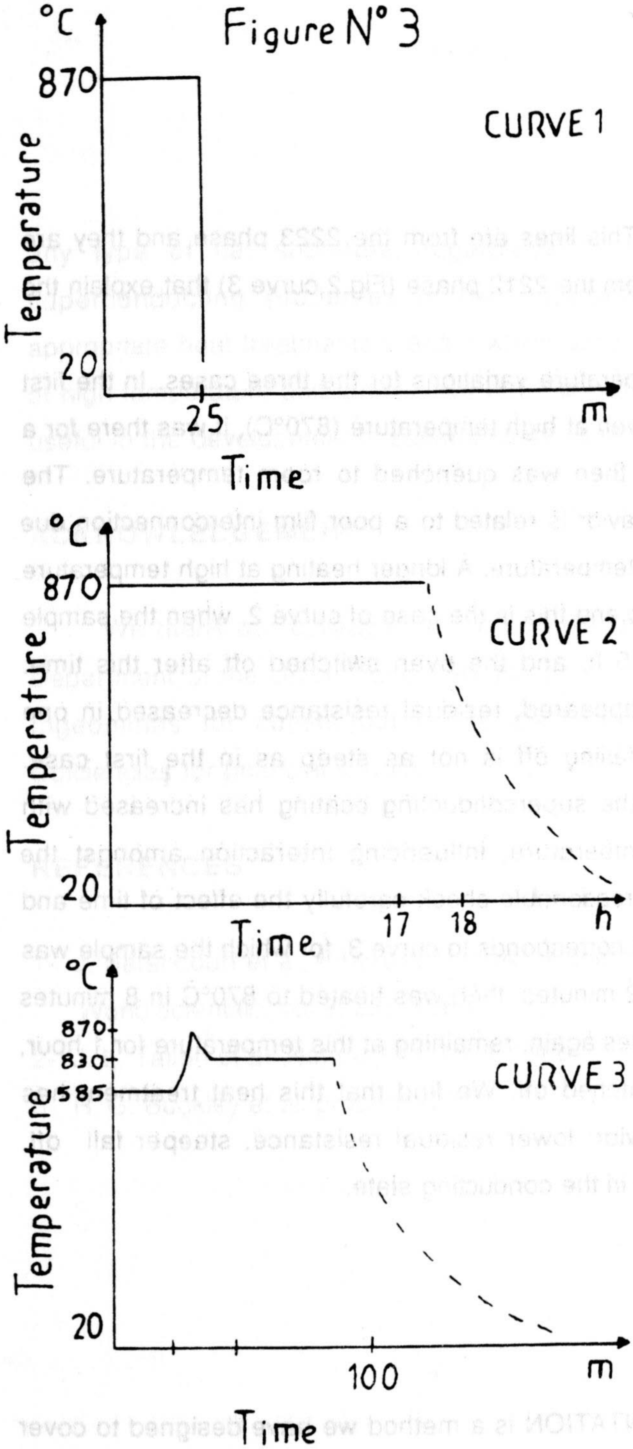

Figure 3. Variations of temperature with time for the three cases of curves 1, 2 and 3 presented in figures 1 and 2.

lines that the previous case. This lines are from the 2223 phase and they are more intensity that the ones from the 2212 phase (Fig.2,curve 3) that explain the high Tc obtained.

Figure 3 shows the temperature variations for the three cases. In the first case, sample was put in the oven at high temperature (870°C), it was there for a short time (25 minutes) and then was quenched to room temperature. The observed semiconducting behavior is related to a poor film interconnection due to the short exposition to high temperature. A longer heating at high temperature must change this characteristic and this is the case of curve 2, when the sample was heated at 870°C for 17.5 h. and the oven switched off after this time. Semiconducting behavior disappeared, residual resistance decreased in one order of magnitude but the falling off is not as steep as in the first case. Interaction of substrate with the superconducting coating has increased with longer exposition at high temperature, influencing interaction amongst the coating grains. It seems then reasonable check carefully the effect of time and temperature as well. The result corresponds to curve 3, for which the sample was put in the oven at 585°C for 22 minutes, then was heated to 870°C in 8 minutes and cooled to 830°C in 8 minutes again, remaining at this temperature for 1 hour, after which the oven was switched off. We find that this heat treatment has improved the thick film behavior: lower residual resistance, steeper fall off, higher Tc and lower resistance in the conducting state.

CONCLUSION

The technique of DECANTATION is a method we have designed to cover any type of flat substrate, regardless its shape. In order to maintain superconducting properties in the deposited materials we have found appropriate heat treatments 2 and 3 which consist basically in long heating time at high temperature and further slow down cooling. This kind of coatings may be useful in the development of superconducting technologies.

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