Physica C 235–240 (1994) 593–594
North-Holland

PHYSICA C

Investigation on the Optimization of YBCO Step-edge Devices

S. Barbanera[b], P. Cikmacs[a] *, P. Cocciolo[a], R. Francini[a], V. Merlo[a], R. Messi[a]

[a] Dipartimento di Fisica, Università di Roma "Tor Vergata"
Via della Ricerca Scientifica 00133 Roma (Italy)

[b] IESS - CNR, Via Cineto Romano, Roma, (Italy)

1 Introduction

In the context of preparation of HTSC step-edge devices, both pattern etching of substrates and smooth and well-oriented thin films are required [1]. In this work we report the results of a systematic study aimed at : 1) optimization of electrical and crystallographic properties of laser-ablation deposited YBCO thin films 2) Realization of sharp steps on MgO substrates. In the following section some information on the apparatus and deposition parameters of YBCO films is first given; this is followed by a brief discussion of results. Finally the three different techniques used to obtain sharp edges of good quality are presented: Ion milling, Sputter etching and Magnetron Reactive Ion Etching (RIE). Some results are also presented and discussed.

2 Experimental

Experimental parameters have been optimized in order to obtain highly c-oriented YBCO thin films, with a smooth surface and a sharp resistive transition. Films have been produced by pulsed laser ablation, using a $XeCl$ laser with $\lambda = 308\ nm$, pulse rate 4 Hz, pulse width 20 ns. Good spatial homogeneity of the laser beam is needed to suppress non-stoichiometric ablation; this has been achieved by careful use of collimating slits. The size of the laser spot on the target has been varied by means of a focalizing lens in order to obtain an energy density $\epsilon = 1.5\ J/cm^2$ on the target. Targets with different densities and thicknesses have been used. We observed a correlation between density and the growth-rate of the film (having fixed ϵ and the pulse rate of the beam). A quartz-made cylindrical oven has been used to achieve a stable and uniform substrate temperature. The deposition temperature has been varied in the range $710 - 760\ ^0C$, in which the films grow c-oriented; the optimum temperature (giving resistive transition temperatures $T_{con} = 92.0\ K$, $T_{coff} = 90.2\ K$ for a film 100 nm thick) varied in the interval $730 - 740\ ^0C$; working at lower temperatures did not change T_{con} appreciably, but a dramatic widening of the transition occurs with $T_{coff} = 82\ K$ for a deposition temperature of $710\ ^0C$. A constant oxygen pressure $P_O = 0.5\ Torr$ was mantained in the chamber during deposition, and a rather standard post-ablation thermal profile has been used: decrease to $450\ ^0C$ with a $18\ ^0C/min$ rate with $P_O = 760\ Torr$, 30 min plateau, free fall down to room temperature. Resistivity curves as a function of temperature (measured with the four-lead technique) are reported in Fig.1, for thicknesses ranging from 20 to 200 nm; we think that the worsening of the transition for the thin films ($d \leq 100\ nm$) is related to surface deterioration due to exposure to atmosphere: a 100 nm thick sample has been protected by evaporating an Ag layer (300 nm thick) and the resistive curve has been compared with that of an unprotected film, giving quantitative support to our feeling; this is also shown in Fig.1, together with the curve taken from the Ag-protected film one year after deposition. In Fig.2 X-ray data taken in the $\theta - 2\theta$ geometry are shown, for films with thicknesses 100 nm and 20 nm respectively. Both films are c-oriented; almost the same results were obtained for the re-

*Permanent Address: Institute for Solid State Physics, University of Latvia, Riga (Latvia)

0921-4534/94/$07.00
SSDI 0921-4534(94)00858-2

maining films, with thickness ranging from 20 to 200 nm.

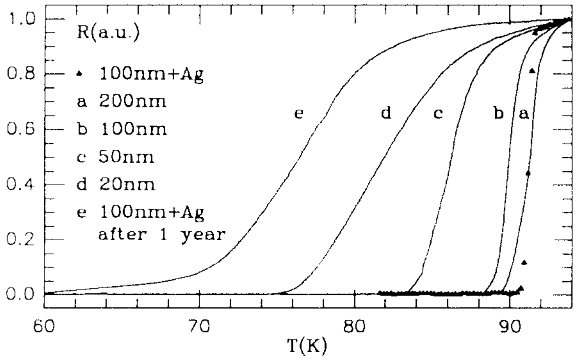

Fig.1 Resistivity curves for films of different thickness.

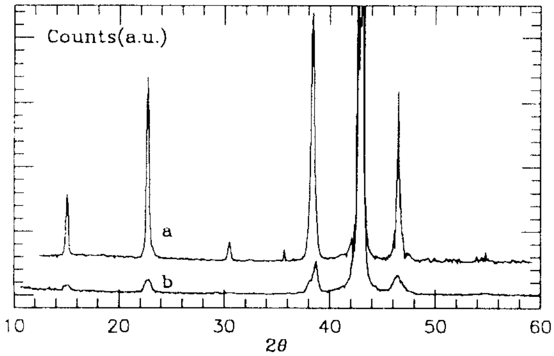

Fig.2 X-ray scans for two films of different thickness: a) 100 nm, b) 20 nm.

In order to obtain the sharpest steps without significant damage of the substrate surface, we tried different methods: Ion Milling, Etch-sputtering, Magnetron RIE. In all cases a Nb mask has been used; the substrate has been coated with a Nb layer and exposed to optical lithography [2]. Nb has been always removed using RIE or chemical etching . Good results have also been obtained with an Al mask using the Etch-sputtering technique with an $Ar - O_2$ mixture. The substrates have been then analysed by SEM to check the status of the surface and the step slope. Best results were obtained using Ion milling, with respect to both the step angle ($\approx 70^0$) and reduced surface damage. Prior to YBCO film deposition, we performed surface reconstruction on each substrate, using flowing Oxygen at $T = 1100\ ^0C$ for 24 hours. After film growth, no appreciable variation of the superconductive properties in the two substrate regions appeared. Good results have been also obtained with Etch-sputtering; however, a SEM analysis shows some overall damage of the eroded surface. In this case, the reconstruction procedure did not give good results: films deposited on these substrates show good crystallographic properties but a somewhat widened transition : $T_{con} = 90.5\ K$, $T_{coff} = 80\ K$ for a film 100 nm thick. No difference in the superconductive properties on either side of the step has been observed. Finally, steps obtained by Magnetron RIE present a non-homogeneous surface erosion. Despite a careful reconstruction procedure, films grown on these substrates are not superconducting; their electrical behaviour looks rather semiconductive.

3 Conclusions

Results of a systematic investigation on deposition parameters of laser ablated YBCO thin films on Mgo substrates have been reported. Using a quartz cylindrical oven and an excimer laser we were able to obtain YBCO highly c-oriented ultra-thin films ($20 - 200 nm$) with good electrical properties ($T_{con} = 92.0\ K$, $T_{coff} = 90.2\ K$ for a film 200 nm thick). Good stability of transport properties has been achieved growing an Ag protective layer on top of the film. Finally, a comparative study of various erosion techniques on MgO substrates has been made; we found that good results in terms of step slope and surface damage can be obtained by Ion Milling and also partially by Etch-sputtering, while Magnetron RIE causes an irreversible damage to the substrate surface with deposition of spurious materials.

References

[1] Y. Zhang, H.M Muck, K. Hermann, J. Schubert, W. Zander, A.I. Braginski and C. Heiden *Appl.Phys.Lett.* **60** (1992) 645

[2] S. Tanaka, H. Kado,T. Matsurand, H. Itozaki, *IEEE Trans.Appl.Superconductivity* **3** (1993) 2365