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Large Area Deposition Of YBaCuO Thin Films By Means Of Hollow Cathode Sputtering

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Abstract
We report on a hollow cathode sputtering technique allowing the deposition of large area YBaCuO thin films on substrates up to 3". The hollow cathode discharge takes place in a single slot with a length of 92 mm. Its walls are covered with YBaCuO bulk material of stoichiometric composition. In order to get a constant film thickness the substrate is moved perpendicular to the hollow cathode slot during the in-situ deposition. YBCO films with good superconducting properties have been obtained with a short sputtering source of 12 mm slot length. In first experiments with the 92 mm-sputtering source the homogeneity of the film thickness has been tested.

1. Introduction

Microelectronical applications of high temperature superconductors (HTSC) require the homogeneous deposition of thin films on large area substrates. One possible configuration consists of a linear hollow cathode discharge sputtering source combined with a substrate movement perpendicular to the hollow cathode slot. The slot is 92 mm long, width and depth are 4 mm and 10 mm, respectively. By using the hollow cathode effect, it is possible to achieve sputtering rates as high as with magnetron sputtering sources [1].

In order to test our configuration for the HTSC deposition, we used at first a sputtering source with a shorter slot length (12 mm instead of 92 mm). Thin films deposited on MgO and $SrTiO_3$ with this short source including the described substrate movement had a T_c of 85 K...90 K and j_c of $10^5...10^6$ A/cm^2 at 77 K. After having obtained these results we constructed a sputtering source with a slot length of 92 mm to deposit films on 3"-substrates.

2. Experimental

The sputtering device consists of a sputtering and an annealing chamber (fig. 1). The sample transfer between them is done by means of a manipulator. The annealing chamber serves as sluice. The Ar/O_2-mixture is tuned by two mass-flow-controllers and passes through the slot supporting the transport of the sputtered material. The movement of the substrate is driven by a motor. In both chambers there are situated identical heaters. We used a coaxial heating wire with cold ends as heating element, which was shrouded with Inconel. The heater reaches a temperature up to 900°C.

The sputtering source (92 mm) is shown in fig. 2. The cathode consists of a slotted, water-cooled copper block, to which adheres the YBaCuO-target of stoichiometric composition. The target-substrate distance can be varied with another manipulator. In order to achieve a homogeneous flow of gas through the cathode, the Ar/O_2-mixture passes through a sintered sheet metal of copper.

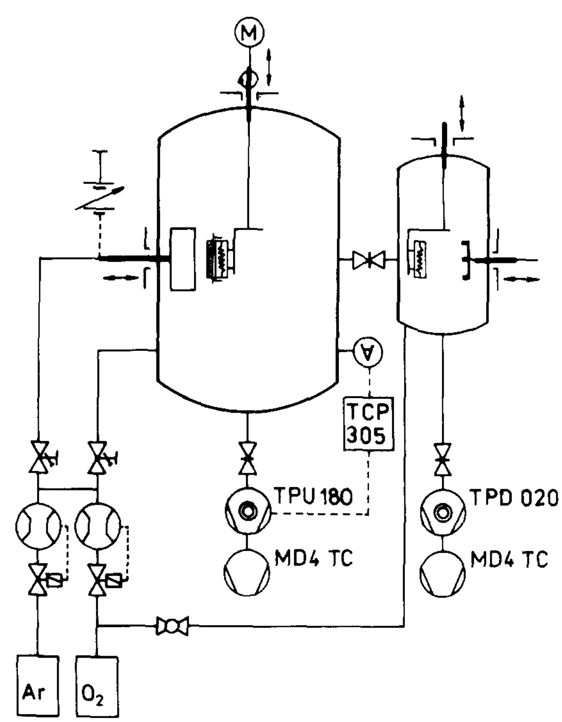

Figure 1. Schematic setup

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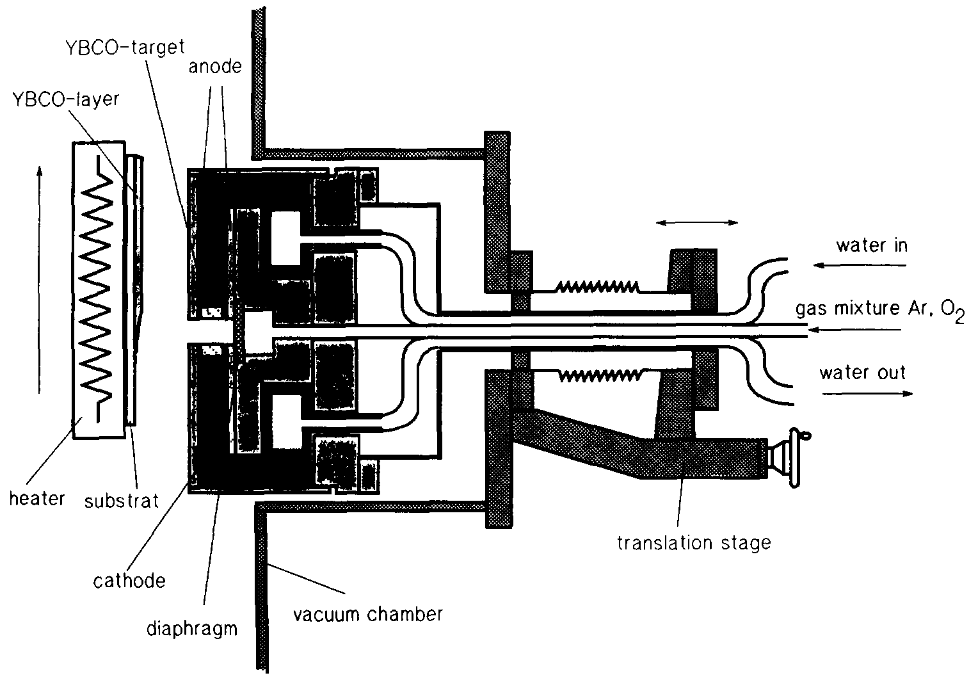

Figure 2. Linear hollow cathode sputtering source (cross view)

3. Results

As stated before, we first used the 12mm-cathode. Experiments with a substrate movement relatively to the slot during the deposition yielded no degradation of the superconducting properties in comparison with films deposited under the same conditions without movement [2].

Putting the 92 mm cathode into operation, there appeared one main problem. The hollow cathode discharge does not take place over the whole slot under any given conditions, but only in a smaller area. Here the oxygen partial pressure, the discharge current and the total pressure are the most significant parameters. In general a high oxygen partial pressure improves the homogenity of the discharge. Due to this problem it was necessary to vary the deposition parameters in order to get a hollow cathode discharge at all. A necessary condition for the hollow cathode discharge is

$$p*d = 0.5 \ldots 5 \text{ mbar cm} \qquad (1)$$

d being the width of the hollow cathode and p the total pressure.

Large area deposition was first tried on unheated 3"-Si-wafers to get information about the homogenity of the film thickness. Before each YBaCuO deposition a careful burn-in procedure has to be performed in order to remove the target surface layer. Our deposition parameters are:

total pressure:	0.5 mbar
flow rate Ar:	30 sccm
flow rate O_2:	30 sccm
ignition voltage:	300 V
discharge voltage:	150...180 V
discharge current:	0.5 A

By means of RBS-measurements a ratio Y:Ba:Cu of 1:1.9:3.4 and a film thickness of about 40 nm were obtained. The relative differences of the film thickness are shown in fig. 3.

The film thickness differs up to 3% to that of the wafer's center, if measured in the movement's direction . However, if measured along a line perpendicular to the direction of the wafer movement, the relative differences reach up to 11%. This is caused by the inhomogeneity of the hollow cathode discharge. Our way to solve this problem is a further optimization of the deposition parameters.

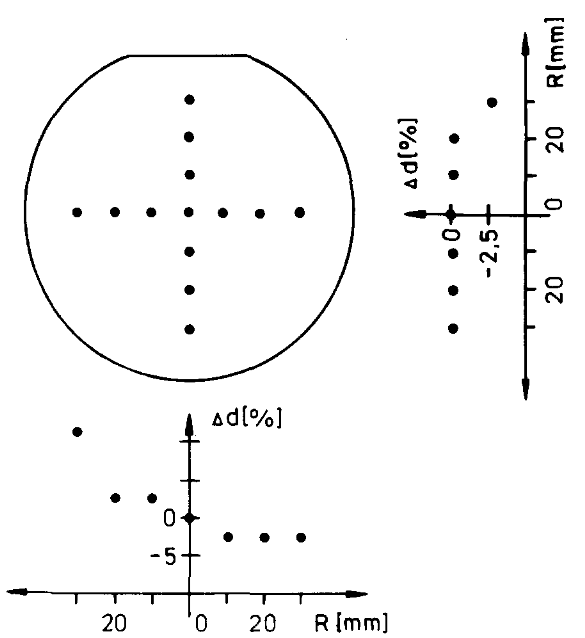

Figure 3. Relative differences of the film thickness

4. Summary

With the long hollow cathode sputtering source it is possible to deposit YBaCuO thin films on 3"-wafers. In contrast to copper hollow cathodes the prolongation of the slot length of those covered with YBaCuO leads to problems with the homogeneity of the hollow cathode discharge. This results in an inhomogeneity of the film thickness perpendicular to the direction of the substrate movement.

Our further investigations are concentrated on optimizing the deposition parameters in order to deposit homogeneous superconducting films with lower differences of the film thickness, in particular perpendicular to the direction of the wafer movement.

Acknowledgement

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