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The preparation of two inch double-sided YBCO thin films

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Abstract
The preparation of two inch double-sided YBCO thin films by simultaneous sputtering from a single target is reported. The lateral homogeneity of microwave surface resistance of the YBCO thin films, on both sides of the two inch wafer, is characterized by using a Fabry–Perot resonator at 145 GHz and 75 K. Values of microwave surface resistance R_s (75 K, 145 GHz, 0 T) below 55 mΩ were reached over the whole area of YBCO thin films on two inch $LaAlO_3$ wafers. The majority of the wafer area has R_s (75 K, 145 GHz, 0 T) values in the range of 15 mΩ to 40 mΩ. The uniformity of R_s values in the whole two inch wafer is excellent and the properties of YBCO thin films were found to be very similar on both sides of the wafer.

1. Introduction

The first commercial application of high-temperature superconductors would be as passive components for microwave devices, such as resonators, filters, multiplexer and antennas associated with mobile communication [1]. The microwave applications generally require large area double-sided $Y_1Ba_2Cu_3O_{7-x}$ (YBCO) thin films with low microwave surface resistance [2–4].

Currently the most successful methods for the preparation of large area double-sided YBCO thin films are sputtering, laser ablation, metalorganic chemical vapour deposition and reactive evaporation [5–8]. Among these methods sputtering is a promising technique for YBCO thin film deposition because of its ease of process control and repeatability of the resulting sample characteristics.

Many groups prepared double-sided YBCO coatings by breaking the vacuum after the first side is deposited, before starting the deposition of the second side [9]. However, simultaneous deposition is preferable for the preparation of double-sided YBCO thin films [10]. Simultaneous coverage of YBCO thin films on both sides of the substrate is reported in this paper. By rotating the substrate around the rod of the substrate holder and the substrate normal (the axis perpendicular to the substrate surface), double-sided YBCO thin films up to two inches in diameter were simultaneously deposited on both sides of (100)$LaAlO_3$ substrates by sputtering from a single target.

2. Experimental details

The set-up used to deposit two inch double-sided YBCO thin films in this work is shown schematically in figure 1. A single inverted cylindrical sputter gun was arranged to simultaneously deposit YBCO thin films on both sides of substrate. The substrate was rotated around the rod of the substrate holder and the substrate normal. The substrates were heated in a tube-like heater.

The target is stoichiometric $Y_1Ba_2Cu_3O_{7-x}$ ceramic. The substrate is (100)$LaAlO_3$. The total sputtering pressure is 40 Pa. The ratio of argon to oxygen is 2:1. The sputtering voltage is 200 V and the sputtering current is 0.4 A. The deposition rate is 0.06 Å s^{-1}. The film thickness is about 4000 Å. The substrate temperature is 860 °C. After deposition the films were cooled down to room temperature slowly in 8×10^4 Pa oxygen in order to take up the full oxygen concentration.

Superconducting transition properties were measured by resistance measurements and inductive measurements. The critical current density J_C of the films were determined by a standard four-probe method with microbridges of 30 μm $\times$ 200 μm patterned by photolithography. The microwave surface resistance R_s was measured by a Fabry–Perot resonator at 145 GHz and 75 K and by a dielectric resonator method operated in the TE_{011} mode at 8.5 GHz. The lateral homogeneity of R_s on the whole two inch wafer was characterized by using the Fabry–Perot resonator method which provides a lateral resolution of 0.6 mm. The dielectric

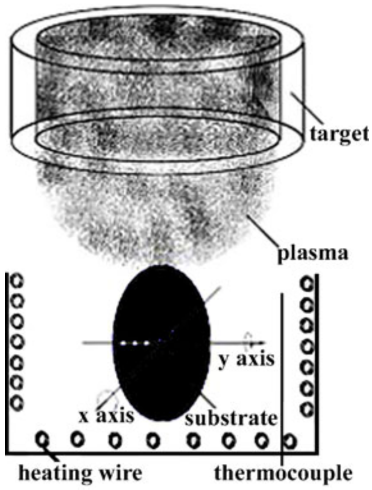

Figure 1. Schematic illustration of the apparatus used in this work.

resonator was used to characterize the power handling capability of the two inch double-sided YBCO thin films.

3. Results

The superconducting transition properties of the YBCO thin films on both sides of the substrate is shown in figure 2. The T_{C0} values are 90.3 K and 90.4 K respectively. The transition width is 0.8 K. The superconducting transition properties of YBCO thin films in different regions of the two inch wafer

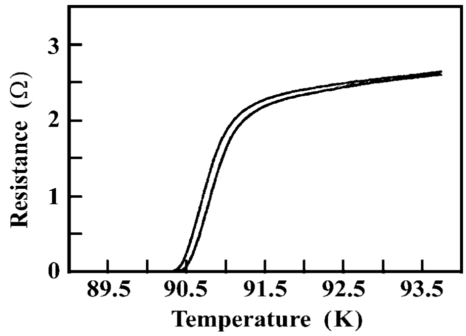

Figure 2. $R(T)$ curves of the YBCO thin films on both sides of the two-inch wafer.

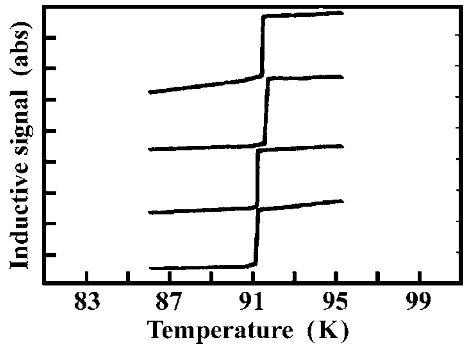

Figure 3. Superconducting transition properties of YBCO thin films in four different regions on the wafer.

is shown in figure 3. The T_C homogeneity of the two inch double-sided YBCO thin films are excellent. T_{C0} values ranged

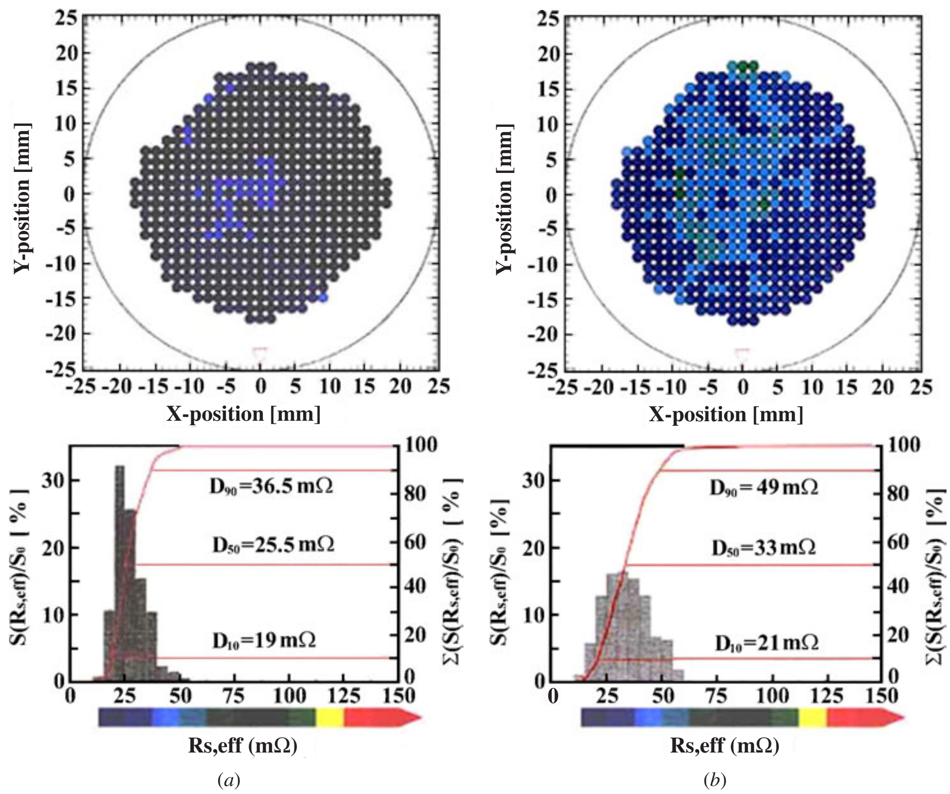

Figure 4. R_s lateral homogeneity of the two inch double-sided YBCO thin films: (*a*) side A; (*b*) side B.

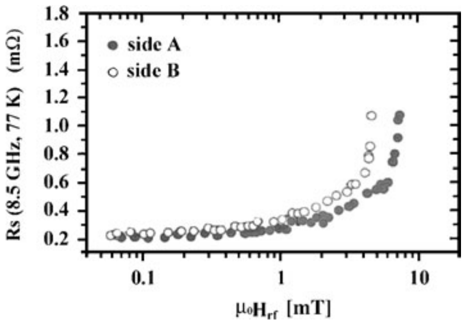

Figure 5. Power handling capability of YBCO films on both sides of the wafer.

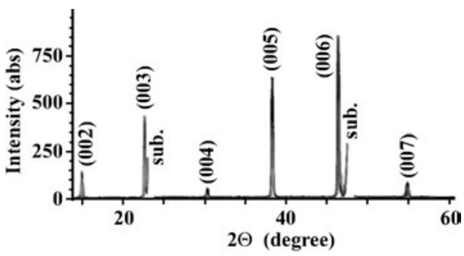

Figure 6. XRD pattern of the two inch double-sided YBCO thin films.

from 89 K to 91 K. The transition width is smaller than 1 K. The critical current density of the films on both sides at 77 K was in the range of 2–3 $\times$ 10^6 A cm^{-2} for a field criteria of 1 μV cm^{-1}.

The microwave resistance lateral homogeneity of the two inch double-sided YBCO thin films is shown in figure 4. The data were collected by measurements at 400 different positions over the entire wafer. The majority of the wafer area on side A has R_s (75 K, 145 GHz, 0 T) in the range of 15 mΩ to 40 mΩ. Ninety per cent of the measuring positions has R_s (75 K, 145 GHz, 0 T) values lower than 36.5 mΩ. According to the ω^2-law, as published by Newman and Lyons, the R_s (77 K, 10 GHz) values on the whole two inch wafer are in the range of 70 $\mu\Omega$–190 $\mu\Omega$. It means that not only the uniformity of the microwave surface resistance is good, but that also the R_s values of the two inch wafer is extremely low. The microwave surface resistance R_s (75 K, 145 GHz) lower than 75 mΩ was reached over the entire area of the wafer on side B. Although the lateral homogeneity of R_s on side B is not as good as that on side A, it is still very homogeneous and the microwave surface resistance is low enough to well meet the microwave applications.

The highest magnetic field $\mu_0 H$, makes the break down of microwave properties of the films 6 mT, as shown in figure 5. R_s (77 K, 8.5 GHz, 0 T) values of YBCO thin films on both sides are 0.2 mΩ. According to the ω^2 law, the R_s (77 K, 10 GHz, 0 T) values are 0.27 mΩ. The consistency between the two sides and the reproducibility are excellent.

The XRD pattern of the two inch double-sided YBCO thin films is shown in figure 6. They are only (0 0 l) lines. It shows that the films are purely *c*-axis oriented. No grains

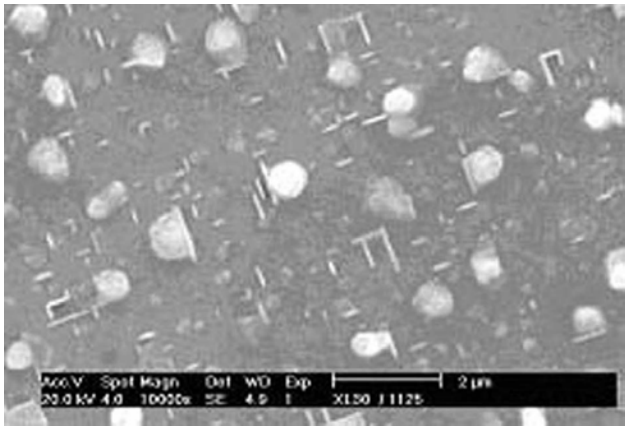

Figure 7. SEM photograph of the two inch double-sided YBCO thin films.

with other orientation and no impurity phases were detected in the films. The ω-scan measurements indicated that the full width at half maximum (FWHM) values of the rocking curves ranged from 0.23° to 0.18°. It shows that the out-of-plane orientation of the films is excellent. In the ϕ-scan spectrum of the films, except the four peaks separated by 90° reflecting the symmetry of YBCO, no other peaks appear in the $\phi-$scan spectrum. It shows that the in-plane orientation of the films is good. There is only one kind of crystallographic orientation relationship between the substrate and film in the a-b plane.

The surface morphology of the films is shown in figure 7. Except for the surface outgrowth, it is homogeneous.

4. Summary

Two inch double-sided YBCO thin films were prepared by simultaneous sputtering from a single target. The properties of the double-sided YBCO thin films were found to be sufficiently uniform and very similiar on both sides of the wafer. The majority of the wafer area has R_s (75 K, 145 GHz, 0 T) in the range of 15 to 40 mΩ. Ninety per cent of the measuring positions has R_s (75 K, 145 GHz, 0 T) lower than 36.5 mΩ.

References

[1] Braginski A I 1999 *IEEE Trans. Appl. Supercond.* **9** 2825
[2] Geerk J, Ratzel F, Rietschel H, Linker G, Heidinger R and Schwab R 1999 *IEEE Trans. Appl. Supercond.* **9** 1543
[3] Norton D P 1998 *Annu. Rev. Mater. Sci.* **28** 299
[4] Li Y R, Liu X Z and Tao B W 2001 *J. Supercond.* **14** 453
[5] Xu J, Li Y R, Tao B W, Liu X Z and Wang H L 2000 *Physica* C **331** 67
[6] Singh R K and Kumar D 1998 *Mater. Sci. Eng.* **R22** 113
[7] Chern B, Martens J S and Li Y Q 1993 *Supercond. Sci. Technol.* **6** 460
[8] Kinder H, Berberich P, Utz B and Prusseit W 1995 *IEEE Trans. Appl. Supercond.* **5** 1576
[9] Müller G *et al* 1997 *IEEE Trans. Appl. Supercond.* **7** 1287
[10] Liu X Z, Tao B W, Luo A, He S M and Li Y R 2001 *Thin Solid Films* **396** 225