Conductor-Backed Coplanar Waveguide Resonators of $YBa_2Cu_3O_{7-\delta}$ on $LaAlO_3$

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Abstract— **Conductor-backed coplanar waveguide (CBCPW) resonators operating at 10.8 GHz have been fabricated from laser ablated and off-axis magnetron sputtered $YBa_2Cu_3O_{7-\delta}$ (YBCO) high-temperature superconducting (HTS) thin films on $LaAlO_3$. These resonators were tested in the temperature range from 14 to 92 K. The unloaded quality factor (Q_0) at 77 K of the HTS CBCPW resonators was 3 to 4 times that of a similar gold (Au) resonator. To our knowledge, these results represent the first reported measurements of HTS-based CBCPW resonators.**

I. Introduction

THE coplanar waveguide (CPW) structure is advantageous for HTS-based microwave IC fabrication mainly because of its geometrical attribute of having the signal ground planes on the same surface as the signal transmission line [1]–[3]. To improve thermal contact between the substrate of the CPW and the cooling fixture, a layer of a good conducting material can be deposited onto the reverse side of the substrate. This conducting layer also acts as an additional ground plane for the structure. When such a ground plane is added, the resulting structure is known as a conductor-backed coplanar waveguide (CBCPW). To date, coplanar superconducting circuit tests have been reported for structures without a back-ground plane, and only at 77 K and 4.2 K [1]–[4]. This letter represents the first report of measurements on several $YBa_2Cu_3O_{7-\delta}$ (YBCO) HTS-based CBCPW resonators from 14 K to 92 K and at 10.8 GHz. The performance of these resonators, as compared with that of an Au-based counterpart is presented.

II. Experimental

The CBCPW resonators analyzed in this study were patterned on laser ablated and off-axis magnetron sputtered $YBa_2Cu_3O_{7-\delta}$ (YBCO) thin films on 1.0 × 1.0 × 0.05 cm (100) $LaAlO_3$ substrates. A schematic of the CBCPW resonator is shown in Fig. 1. This pattern was transferred to the HTS films using standard photolithography techniques and a subsequent "back-etching" process using a 1% phosphoric acid (H_3PO_4) solution. Afterwards, the ground plane on the opposite side of the substrate was formed by evaporation of a Au layer ~2.5 μm thick on top of a Chromium layer (~150 Å) previously evaporated on the $LaAlO_3$ to improve Au adhesion. For comparison purposes, a similar resonator was made with its CPW part consisting of an evaporated Au layer ~1.2 μm thick. The length (L2) and width (S) of the center conductor were 7.020 mm and 0.200 mm, respectively. The gaps on each side (W) and at the bottom (G2) of the resonator were 0.530 mm, and G3 was 0.630 mm. The coupling between the external coaxial lines and the resonator was achieved through an SMA launcher. The center pin of the connector was placed in direct contact with the feed line that tapered from 0.559 mm to the width of the center conductor over a length L1 of 1.000 mm. Coupling to the resonator was achieved across a gap (G1) 0.050 mm wide. To improve the contact between the launcher and the feed line, silver (Ag) contacts (~2500 Å thick) were evaporated onto the end of the feed line and the coplanar ground planes. The transition temperature ($T_c(R{=}0)$) of the resonators after being patterned was measured using standard four-point probe techniques. The measured T_c values were 91.1 K, 89.9 K, and 84 K, for samples 1 (laser ablated), 2 (magnetron sputtered), and 3 (laser ablated), respectively. Each resonator was mounted on a brass test fixture which was bolted to the cold finger of a close-cycle-helium-gas refrigerator and enclosed inside a vacuum can. The reflection coefficient of the circuit was measured using an HP-8510C network analyzer, and was used to determine the unloaded quality factor (Q_0) of the resonator according to the procedure described in [5]. The network analyzer was calibrated with short, open, and load standards before the beginning of each measurement cycle.

III. Results

The results of the measurements on the CBCPW resonators are summarized in Table I. Films thickness and T_c values were measured after patterning. The Q_0's versus temperature for the resonators tested in this study are shown in Fig. 2. The results show that sample 2 has the highest Q_0 values for the temperature range in common for all the resonators. Its Q_0 at 77 K and 10.8 GHz was 470, which is approximately four times better than that of the Au resonator at the same temperature and frequency. However, this value is approximately 0.4 of the best reported value for laser ablated YBCO-based CPW structures at 8.8 GHz and 77 K [6]. This reduction may be due to the effect of adding a back conductor.

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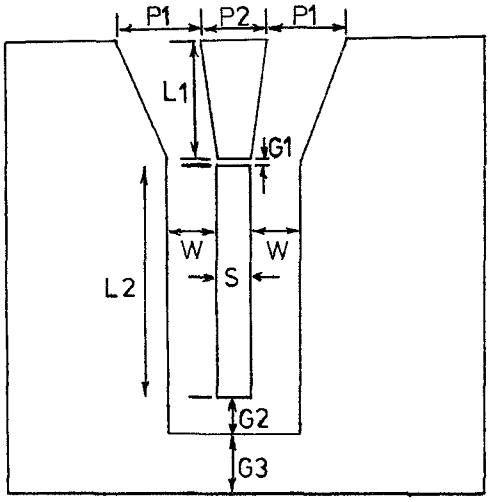

Fig. 1. Top view of the conductor-backed coplanar waveguide (CBCPW) resonator (9.230 × 9 230 mm). P1 = 0.533 mm, P2 = 0.559 mm, L1 = 1.000 mm, L2 = 7.020 mm, W = 0.530 mm, S = 0.200 mm, G1 = 0.050 mm, G2 = 0.530 mm, and G3 = 0.630 mm. The relative dielectric constant (ϵ_r) of the substrate is 22.

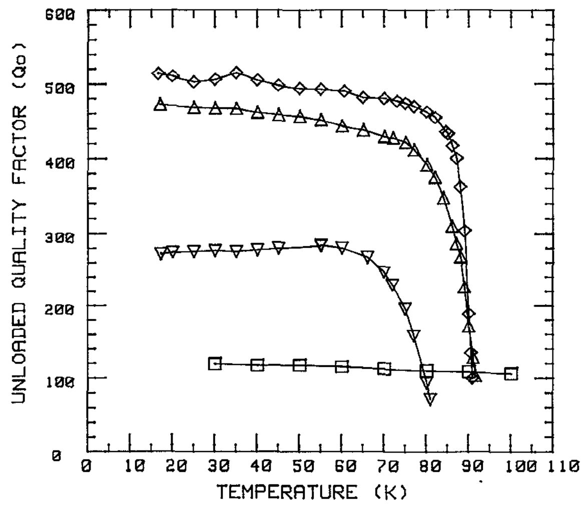

Fig. 2 Unloaded quality factor (Q_0) versus temperature for a Au (□), and YBCO CBCPW resonators on $LaAlO_3$; sample 1 (△; laser ablated), sample 2 (◇; off-axis magnetron sputtered), sample 3 (▽; laser ablated).

TABLE I
FILM PROPERTIES OF CONDUCTOR-BACKED COPLANAR WAVEGUIDE RRESONATORS

Sample	Deposition Temp. (°C)	Film Thickness (nm)	T_c(K)[a]	Q_0(77 K)[b]	f_0(GHz: @ 77 K)[c]
Au		1200		110	10.803
1	715	350	91.1	412	10.805
2		350	89.9	470	10.755
3	715	310	84.0	159	10.662

[a] dc transition temperature.
[b] Unloaded quality factor.
[c] Resonance frequency.

For microwave applications an HTS-based resonator should be characterized by a high T_c (~90 K), a rapid increase in Q_0 as the sample is cooled below T_c, and a fast stabilization of the Q_0 with respect to temperature at temperatures not far below T_c. Of the three resonators under study, samples 1 and 2 seem to satisfy these demands. However, although resonances for samples 1 and 2 were observed around the same temperature (~91 K), the increase in Q_0 with decreasing temperature for sample 1 is not as sharp as that for sample 2. The behavior of sample 1 as compare with sample 2 could be associated with a higher degree of homogeneity for the sputtered film than that attained for the laser ablated one for which the more gradual change of the Q_0 with temperature may be a consequence of a distribution of T_c's from grain to grain and other film inhomogeneities. However, the closeness of the Q_0 values for these samples indicates that films suitable for microwave applications can be obtained by off-axis magnetron sputtering as well as laser ablation.

IV. CONCLUSION

Conductor-backed coplanar waveguide (CBCPW) resonators have been patterned on laser ablated and off-axis magnetron sputtered YBCO HTS thin films on $LaAlO_3$. These resonators were tested in the temperature range from 14 to 92 K and an unloaded quality factor Q_0 as high as 470 was obtained at 10.8 GHz and 77 K. This value is four times higher than that of a similar all Au resonator at the same frequency and temperature. We found that similar Q_0 values were obtained for CBCPW resonators fabricated on both off-axis magnetron sputtered and laser ablated YBCO thin films of comparable T_c's.

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