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STUDY OF DEPOSITION OF $YBa_2Cu_3O_{7-x}$ ON CUBIC ZIRCONIA

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ABSTRACT

Films of $YBa_2Cu_3O_{7-x}$ have been grown on (100) cubic zirconia with 8 percent yttria by laser ablation from sintered targets of $YBa_2Cu_3O_{7-x}$. The temperature of the zirconia substrate during growth was varied between 700 and 780 °C. The atmosphere during growth was 170 mtorr of oxygen. The films were subsequently slowly cooled in-situ in 1 atm of oxygen. The best films were c-axis aligned and had a transition temperature of 87.7 K. The superconducting transition temperature and the x-ray diffraction analysis will be reported as a function of the substrate temperature and of the angle between the laser beam and the target's normal.

INTRODUCTION

Laser ablation of high temperature superconducting (HTS) thin films has been shown to give high-quality films on $SrTiO_3$.[1-6] For microwave applications, however, a high-quality film is not enough. The substrate must also have low losses. Unfortunately, $SrTiO_3$ does not have low microwave losses. Therefore, in investigating HTS films for microwave applications, we have chosen as a substrate cubic zirconia stabilized with 8 percent yttria. It has a real dielectric constant of 25.4 and an imaginary dielectric constant of 1.74 at 33 GHz.[7] This is suitable for many microwave applications for space communications.

EXPERIMENTAL PROCEDURE

The laser ablation technique is similar to that which other researchers have used.[1-6] The details of the geometry are shown in Fig. 1. The substrates used were polished (100) cubic zirconia obtained from Atomergic Corporation. The samples were degreased in acetone and methanol prior to being glued with silver paint to the stainless steel sample holder. The paint was cured at 200 °C for 15 min in air and

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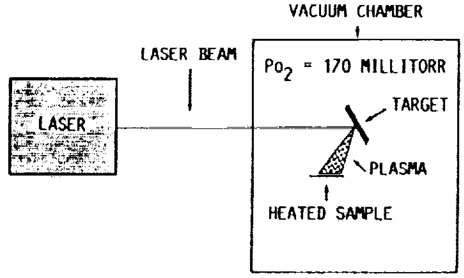


FIGURE 1. - SCHEMATIC OF LASER ABLATION EXPERIMENT.

allowed to cool before being placed in the vacuum chamber. The chamber was evacuated to $2x10^{-7}$ torr or less using a liquid nitrogen cold trapped diffusion pump before the sample was warmed to 500 °C within 30 min. A continuous flow of oxygen (120 sccm) was then introduced into the chamber, and the sample was heated to its final temperature using resistive heating. The temperature was measured by a type K thermocouple that was welded to the stainless plate. The samples were within 5 mm of the thermocouple. During deposition the pressure was 170 mtorr, the laser wavelength was 248 nm, the energy density was 1.5 J/cm^2/pulse, the pulse rate was 4 pps, the distance between the target and the sample was 7.5 cm, and the laser beam was scanned up and down 1 cm over the target using an external lens on a translator. The angle between the normal of the target and the laser beam α was either 15°, 20°, or 45°.

After deposition the oxygen pressure was raised to 1 atm and the temperature was lowered to 450 °C at a rate of 2 °C/min. The temperature was held at 450 °C for 2 hr before it was lowered to 250 °C at a rate of 2 °C/min. The heater power was then turned off and the sample was allowed to cool to 40 °C or less before it was removed from the chamber.

Resistance was measured using a standard 4-point probe technique and with a current density between 4 to 10 A/cm^2. The contacts to the sample were made by wire bonding directly to the samples with 1 by 2 mil gold ribbon. The spacing between the voltage leads was approximately 3 mm.

RESULTS

The transition temperatures T_c of several samples for different α's and different deposition temperatures T_d are given in Table 1. As can be seen for the samples deposited, when $\alpha = 20°$, a change of 5 °C in T_d can result in a change in T_c of 3 to 10 K. The best films were for $\alpha = 45°$ and $T_d = 772$ °C. When the films made at $\alpha = 15°$ and $\alpha = 20°$ are compared, it can be seen that the lower angle gave a higher T_c for a lower T_d.

We observe that the intercept on the normal resistance axis is correlated with T_c. The closer the intercept is to 0 the higher Tc is. This is illustrated in Fig. 2 by samples 1 and 5. Film 1 had a T_d of 772 °C and a T_c of 87.7 K, while sample 5 had a T_d of 751 °C and a T_c of 75.8 K.

The difference between high T_c HTS films and lower T_c HTS films can also be seen in the morphology. Figure 3(a) is a scanning tunneling micrograph (SEM) of a film grown at $\alpha = 20°$ and $T_d = 751$ °C with $T_c = 80.1$ K. One can see the extreme roughness in the surface caused by 1 μ-size crystals growing on the surface. In contrast, in Fig. 3(b) the

TABLE 1. - TRANSITION TEMPERATURE T_c OF $YBu_2Cu_3O_x$ THIN FILMS ON CUBIC ZIRCONIA FOR VARIOUS DEPOSITION TEMPERATURES AND ANGLES BETWEEN THE TARGET'S NORMAL AND THE LASER BEAM

Sample number	Angle between laser beam and target's normal, deg	Deposition temperature, T_d, °C	Transition temperature, T_c, K
1	45	772	87.7
2	45	772	87.7
3	20	764	83.1
4	20	755	86.0
5	20	751	75.8
6	15	719	83.5
7	15	699	71.3
8	15	696	74.0

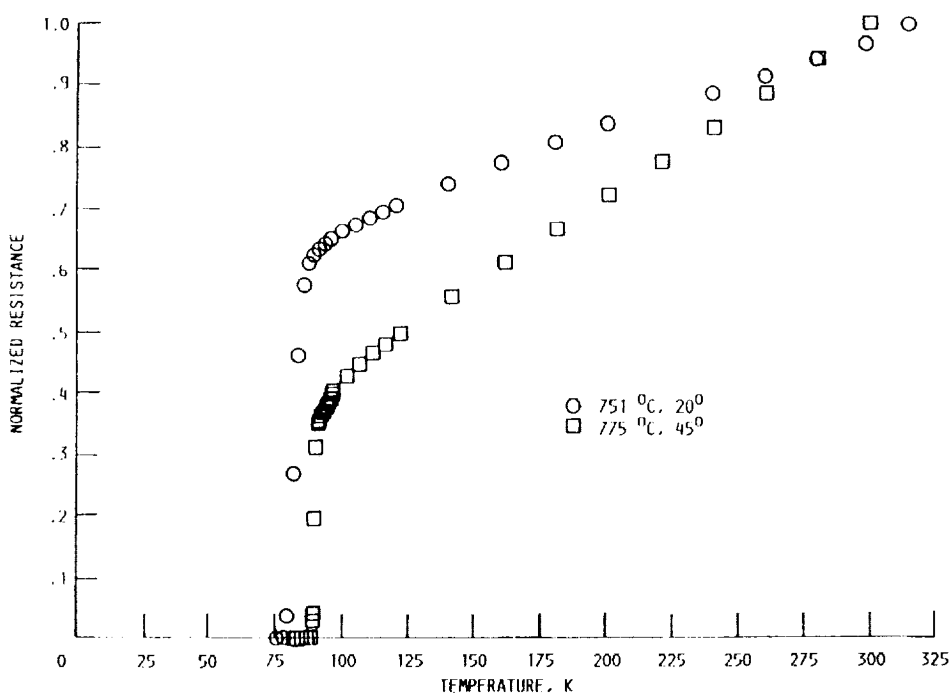
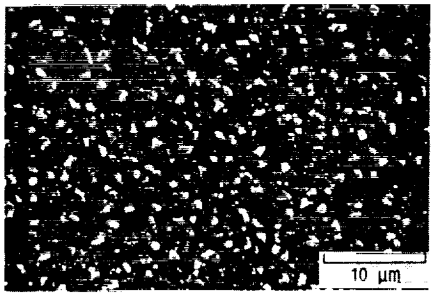
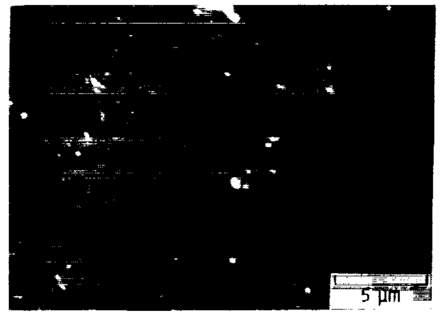


FIGURE 2. - NORMALIZED RESISTANCE OF $YBa_2Cu_3O_x$ FILMS ON CUBIC ZIRCONIA MADE BY LASER ABLATION DIFFERENT DEPOSITION TEMPERATURE AND DIFFERENT ANGLE BETWEEN THE LASER BEAM AND THE TARGETS NORMAL.





(a) FILM DEPOSITED AT 751 °C WITH A T_c OF 81 K. (b) FILM DEPOSITED AT 775 °C WITH A T_c AT 86.4 K.

FIGURE 3. - SCANNING ELECTRON MICROGRAPH OF LASER-ABLATED $YBa_2Cu_3O_x$ THIN FILM ON CUBIC ZIRCONIA.

film was grown at $\alpha = 45°$ and $T_d = 772$ °C with $T_c = 87.7$ K. This film was smooth with a very low density of particles on the surface.

The x-ray diffraction pattern of the film in Fig. 3(a) is shown in Fig. 4. All the major peaks are either from $YBa_2Cu_3O_x$ or from cubic zirconia. The 2-θ angle full width of half maximum of the $YBa_2Cu_3O_x$ (005) line is 1.3°. This condition indicates that the film was oriented.

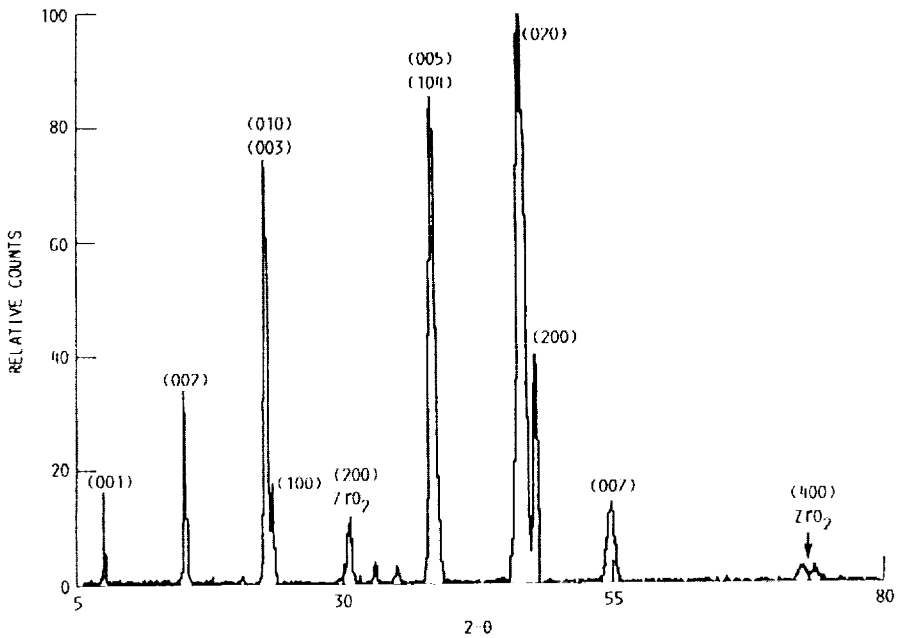


FIGURE 4. - X-RAY DIFFRACTION OF $YBa_2Cu_3O_x$ FILM ON CUBIC ZIRCONIA. FILM DEPOSITED AT 751 °C WITH A T_c OF 81 K.

CONCLUSIONS

To conclude, high-quality $YBa_2Cu_3O_x$ thin films have been grown on cubic zirconia ($(ZrO_2)_{0.92}$ $(Y_2O_3)_{0.08}$) with a T_c as high as 87.7 K. The best films were smooth and had few particles on the surface. The transition temperature of the film was found to be highly dependent on both the deposition temperature and the angle between the normal of the target and the laser beam. To obtain the highest T_c and have it be

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reproducible, the temperature of the substrate must be held within 3 °C. To grow films with high T_c at lower temperatures in a partial oxygen atmosphere, the angle α must be as small as possible.

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FIGURE CAPTIONS

Figure 1. - Schematic of laser ablation experiment.

Figure 2. - Normalized resistance of $YBa_2Cu_3O_x$ films on cubic zirconia made by laser ablation different deposition temperature and different angle between the laser beam and the targets normal. +(751 °C and 20°), (775 °C and 45°)

Figure 3. - Scanning electron micrograph of laser ablated $YBa_2Cu_3O_x$ thin film on cubic zirconia. (a) Film was deposited at 751 °C and had a T_c of 81 K. (b) Film was deposited at 775 °C and had a T_c of 86.4 K.

Figure 4. - X-ray diffraction of $YBa_2Cu_3O_x$ film on cubic zirconia. The film was deposited at 751 °C with a T_c of 81 K.

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