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FAST ONE STEP PREPARATION OF HIGH QUALITY $YBA_2Cu_3O_{7-x}$ THIN FILMS BY LASER ABLATION

J. FRÖHLINGSDORF*, P. LEIDERER+, R. FEILE++, W. ZANDER*, B. STRITZKER*

* Institut für Schicht- und Ionentechnik, KFA Jülich, FRG
\+ Fakultät für Physik, Universität Konstanz, FRG
++ Institut für Physik, Universität Mainz, FRG

Thin films of $YBa_2Cu_3O_{7-x}$ have been produced in situ by laser ablation without further low temperature annealing. Films were found to be polycrystalline with the c-axis preferentially oriented normal to the substrate plane on single crystalline (001)-$SrTiO_3$ and (random)-ZrO_2. Complete superconducting transitions above 92 K with transition widths of about 1 K have been observed even on YSZ substrates. Critical current densities, jc (77 K), of more than 1.5 x 10^6 A/cm^2 could be obtained on $SrTiO_3$-substrates. This new technique enables deposition of films as thin as 10 nm with excellent superconducting properties; it requires short process times (< 5 min) and is a versatile method which is also applicable to other materials. The high quality of the thin films over large areas was demonstrated by the measurement of persistent superconducting current densities (77 K) of several 10^5 A/cm^2 in a 1 mm broad ring of 9 mm diameter. No dissipation of this persistent current could be observed during one hour.

1. INTRODUCTION

One of the most important properties of a superconductor is its critical current density. For the laser ablated films discussed here, we did two sets of measurements:

a) The critical current density in a 20 μm wide and 400 μm long bridge.

b) The persistent current density in a macroscopic superconducting ring (9 mm outer diameter, 1.5 mm width).

The structuring for both method was done by laser etching using a thin wire mask (a) or a ring mask (b).

2. EXPERIMENTAL

Preparation by laser ablation [1]:

Single phase orthorhombic materials of the nominal composition $YBa_2Cu_3O_{7-x}$ with a T_c of about 92 K and transition width of less than 1 K was grinded and sintered into pellets. These targets were used for laser ablation, as described in [2].

For the persistent current measurement a film of 450 nm thickness was evaporated. T_c (R=0) was at 88 K, a typical value for such a thick film. Then laser etching removed this film completely in all areas which were not covered by a ring mask. The resulting superconducting ring (Ø = 9mm) was used for the further measurements.

Persistent current measurements:

Persistent currents in this sample were determined via the spatial distribution of their magnetic field, as described earlier [3]. The detector was a small, rectangular pick-up coil (length l = 10 mm, width w = 1.5 mm, thickness b = 0.8 mm), which was vibrated by a piezoelectric bimorph in such a mode that mainly the end, A, facing the sample was in motion and the opposite side was nearly at rest (see [3]). In this way the coil acts as a local detector, registering essentially only the magnetic field perpendicular to the sample plane at position A.

3. RESULTS AND DISCUSSION

Single step fabrication of crystalline superconducting films, in our opinion, requires elevated substrate temperatures and high O_2 partial pressure in the vacuum chamber. Our best results were obtained at substrate surface temperature of about 780°C and a base pressure of 1 mbar O_2. Films with T_c (R=O) ~ 92 K, j_c (77K) > 1.5 x 10^6 A/cm^2 and thickness of about 500 nm could be obtained within 5 minutes including heating, ventilation and unmounting (for details see [2]).

The overall quality of the superconducting films over a large area was checked by the persistent current measurement. A crucial question is whether the persistent currents truly do follow a closed path around the ring or whether they are localized to certain portions of the film. The spatial distribution of the magnetic field of a ring-shaped sample allows one to distinguish, unequivocally, between these possibilities:

i.) For a ring current, a field distribution such as the one in Fig. 1 is expected.

ii.) Conversely, if the ring current is suppressed by imperfections or by a scratch, so that the magnetic field is due only to flux trapped within the ring material itself, the field in the center has, then, the opposite sign and is much weaker than directly above the superconducting films [3].

The results of these measurements can be summarized as follows (a detailed discussion is given in [4]):

The measured field distribution is the expected one for a macroscopic ring current (Fig. 1). These persistent currents exist in the textured films at 77 K under different conditions for field-cooled and zero-field-cooled samples. The value obtained for the critical current density of this macroscopic current is 0.9 x 10^5 A/cm^2 in all cases: The macroscopic ring current does not decay over time periods in the order of hours.

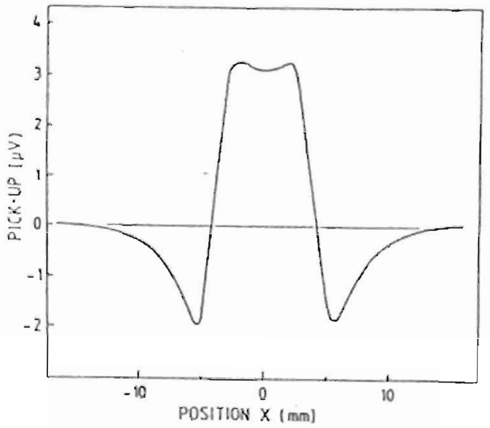

FIGURE 1:
Pick-up signal of the vibrating detector, proportional to the local magnetic filed B(x), for a flat calibration coil.

The critical macroscopic current density does not depend on the presence of an external magnetic field of about 50 Gauss. This is in contrast to polycrystalline samples where a field of some 10 Gauss is known to destroy the superconducting contacts between the grains. Our results suggest that the fabrication of devices which rely on dissipationless current transport should be possible with these laser-deposited films even on relatively large scales in the range of centimeters.

REFERENCES

1. D. Dijkkamp, T. Venkatesan, X.D. Wu, S.A. Shaheen, N. Jisrawi, Y.H. Min-Lee, W.L. Mc Lean and M. Croft, Appl. Phys. Lett, 51 (1987) 619
2. J. Fröhlingsdorf, W. Zander and B. Stritzker, Sol. State Comm. 67 (10), (1988) 965
3. P. Leiderer and R. Feile, Z. Phys. B70, 141 (1988)
4. J. Fröhlingsdorf, W. Zander, B. Stritzker, R. Feile and P. Leiderer, to be published in Physica C.