Appl. Phys. A 48, 501–502 (1989)

Applied Physics A Solids and Surfaces

© Springer-Verlag 1989

Rapid Communication

Preparation of Tl-Ba-Ca-Cu-O Thin Films by Diffusion of Tl into Laser Evaporated $Ba_2Ca_2Cu_3O_x$ Films

H. Lengfellner, J. Betz, and K. F. Renk

Fakultät Physik, Universität, D-8400 Regensburg, Fed. Rep. Germany

Received 9 March 1989/Accepted 20 March 1989

Abstract. Preparation of superconducting Tl-Ba-Ca-Cu-O thin films by diffusion of Tl into laser evaporated $Ba_2Ca_2Cu_3O_x$ thin films is reported. From a sintered $Ba_2Ca_2Cu_3O_x$ bulk sample we prepared using a pulsed Nd:YAG laser, Ba-Ca-Cu-O thin films on sapphire and $SrTiO_3$ single-crystal substrates. Subsequently the films were loaded with Tl by simultaneously annealing the films together with a sintered $Tl_2Ba_2Ca_2Cu_3O_{10}$ sample both enclosed in a small stainless steel box; in our procedure Tl contamination was reduced to a minimum. T_c values near 100 K and critical currents of $5\cdot10^3$ A/cm^2 at 77 K were obtained.

PACS: 74.70, 74.75

After the discovery of superconductivity in Tl-Ba-Ca-Cu-O compounds [1], thin films of this material have been obtained by electron beam evaporation [2] and sputtering techniques [3-5]; critical currents of 10^4-10^5 A/cm^2 at 77 K have been reported [2-5]. Tl-Ba-Ca-Cu-O films have also been prepared by rf sputtering of a Ba-Ca-Cu-O film and a subsequent heat treatment for diffusion of Tl into the film [6]. As a Tl source a piece of metallic Tl was used, and zero resistance was reached at about 75 K [6]. We have developed a similar film preparation method, using, however, a laser evaporation technique and a modified Tl diffusion procedure. We obtained films with a superconducting transition temperature near 100 K and critical currents of about $5\cdot10^3$ A/cm^2 at 77 K.

For the preparation of Tl-Ba-Ca-Cu-O thin films used was made of a standard sintered $Tl_2Ba_2Ca_2Cu_3O_{10}$ sample and a sintered $Ba_2Ca_2Cu_3O_x$ sample. The (nonmetallic) $Ba_2Ca_2\cdot Cu_3O_x$ sample was prepared by using and grinding appropriate amounts of $CaCO_3$, $BaCO_3$ and CuO, pressing to a pellet (with 2 tons/cm^2) and sintering at 900°C for 10 h in oxygen atmosphere. From this pellet, a thin film was laser evaporated onto sapphire and $SrTiO_2$ single crystal substrates (heated to 400°C). The substrate was located in the evaporation cone at a distance of about 2 cm from the pellet. The slightly focused beam (diameter: ≃2mm) of a pulsed Nd: YAG laser (pulse duration: 50ns, pulse energy: 200mJ) was directed onto the slowly rotating target pellet mounted in a vacuum system ($5\cdot10^{-5}$ Torr during evaporation). Material from the target evaporated perpendicular to the target surface. Our arrangement is described in more detail elsewhere [7]. In the next preparation step the film and a $Tl_2Ba_2Ca_2Cu_3O_{10}$ bulk sample were placed in a small stainless steel box (3x2x2cm^3); a stainless steel ring (diameter: 10mm, thickness: 1mm) served as a spacer between film and bulk sample. The (closed) box was put into a preheated tube furnace (at 880°C) for 5 min and then taken out and quickly cooled to room temperature. Our film had a diameter of about 6 mm and a thickness of about 1 μm (after 5000 laser shots). We note here that we also tried the Tl-loading step with a small amount of Tl_2O_3 powder instead of the $Tl_2Ba_2Ca_2Cu_3O_{10}$ bulk

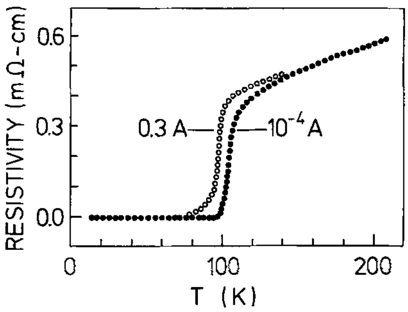

Fig.1. Resistivity versus temperature for a Tl-Ba-Ca-Cu-O film on $SrTiO_3$, for currents of 10^{-4} A and 0.3 A, respectively

sample, but did not succeed in obtaining superconducting films.

Conductivity and critical current measurements were performed by a standard four-point technique; contacts were made with silver epoxy paint. The resistivity at room temperature was about 0.7 mΩ·cm for a film on a (100) $SrTiO_3$ substrate. The resistivity decreased almost linearly between 300 and 150 K, a deviation from this behavior was observed below 140 K (Fig.1). We obtained T_c values of 100-117 K (10-90%) for the resistive transition, with $T_c^{R=0}$ at 96 K. Similar results with respect to resistivity values have been obtained for a film on a sapphire substrate; $T_c^{R=0}$ was 93 K for this film.

The resistivities were measured with small currents (10^{-4}A). For a measurement of the critical current, we increased the current through the film. In Fig.1, the slope of the resistivity obtained with a current of 0.3 A (dotted line) is also shown. The film showed non-zero resistance for temperatures above 77 K. We increased the current, with the film immersed in liquid helium, up to 0.5 A. At a higher current the film was destroyed, probably due to imcomplete cooling of the contact regions. From these observations we obtained lower limits for the critical currents of about $5 \cdot 10^3$ A/cm^2 at 77 K and of 10^4 A/cm^2 at 4.2 K.

In conclusion, we have shown that Tl-Ba-Ca-Cu-O films with high values for T_c and for the critical current can be produced using a laser evaporation technique for the production of a Tl-free Ba-Ca-Cu-O film and a subsequent Tl diffusion step to load the film with Tl. The use of $Tl_2Ba_2Ca_2Cu_3O_{10}$ bulk samples as a Tl source in an enclosed environment seems to be important for the diffusion procedure.

References

1. Z.Z. Sheng, A.M. Hermann: Nature 332, 138 (1988)
2. D.S. Ginley, J.F. Kwak, R.P. Hellmer, R.J. Baughman, E.L. Venturini, B. Morosin: Appl. Phys. Lett. 53, 406 (1988)
3. Y. Ichikawa, H. Adachi, K. Setsune, S. Hatta, K. Hirochi, K. Wasa: Appl. Phys. Lett. 53, 919 (1988)
4. M. Hong, S.H. Liou, D.D. Bacon, G.S. Grader, J. Kwo, A.R. Kortan, B.A. Davidson: Appl. Phys. Lett. 53, 2102 (1988)
5. W.Y. Lee, V.Y. Lee, J. Salem, T.C. Huang, R. Savoy, D.C. Bullock, S.S.P. Parkin: Appl. Phys. Lett. 53, 329 (1988)
6. C.X. Qiu, I. Shih: Appl. Phys. Lett. 53, 1122 (1988)
7. H. Lengfellner. K.F. Renk, P. Fickenscher, W. Schindler: J. Phys. D 22, 323 (1989)

Responsible for Advertisements: E. Lückermann, G. Probst, Heidelberger Platz 3, D-1000 Berlin 33, Tel. (030) 8207-0, Telex 01-85411, FAX (0)30/8214091
Responsible for the Text: H. K. V. Lotsch, Tiergartenstrasse 17, D-6900 Heidelberg, Tel. (0) 6221/487253, Telex 461 723, FAX (0) 6221/43982
Printers: Brühlsche Universitätsdruckerei, Giessen
© by Springer-Verlag Berlin Heidelberg 1989. Printed in Germany
Springer-Verlag GmbH & Co. KG, D-1000 Berlin 33