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Role of a silver buffer layer on the superconducting Y–Ba–Cu–O films deposited by screen printing on alumina substrates

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The characteristics of Y–Ba–Cu–O superconducting films, prepared on alumina substrates with an intermediate layer of thick film high-temperature silver paste, are studied. It is found that the critical current density of the film has improved, perhaps due to the prevention of interactions between alumina and the superconducting film by the intermediate layer.

1. Introduction

A few high-temperature superconducting components, such as current-controlled resistors [1] and Josephson junctions [2] have been prepared using thick and thin film technologies. These components use materials such as yttria-stabilized zirconia as substrates. The conventional thick- and thin-film circuits, however, use alumina substrates for reasons of economy [3]. If the high-temperature superconducting film components are to find a place along with other electronic components, they must be fabricated on the same alumina substrates. But it has been reported [4–10] that the effective critical current density of Y–Ba–Cu–O films prepared by printing on alumina substrates is small. This has been shown to be due to the chemical interaction between the alumina substrate and Y–Ba–Cu–O active material. Hence there is a need to develop a technique by which the critical currents of these films can be improved. With this in view, Y–Ba–Cu–O films have been prepared on substrates which have already been coated with a layer of thick-film high-temperature silver paste, by thick film technology. These films have shown relatively higher critical currents.

2. Experimental procedure

The substrates used in this investigation were high-alumina (96% Al_2O_3) substrates. The inhibiting layer is deposited on the substrates by screen printing a thick-film-conducting ink (Eltecks 1335-C, a composite of silver and frit glass) through a 200-mesh stainless steel screen. The printed film is dried at 150 °C for 15 min and then dried at 800 °C for 30 min. During firing, the glass melts, flows and binds the film to the substrate.

These substrates with a silver composite layer were used for depositing the Y–Ba–Cu–O film by the method described in the previous communication [1]. In this, a mixture of powders of Y_2O_3, $BaCO_3$ and CuO in appropriate proportions (200, 700 and 422 mg, respectively) was made into a paste using an organic vehicle such as triethanolamine. This paste was printed on the substrate with the inhibitor layer. The printed film was dried at about 200 °C for 20 min. These films were then pre-fired in a muffle furnace at 600 °C for 60 min, then sintered at 950 °C for various periods in the range 30 to 120 min. The final sintering temperature was, however, limited to 950 °C as it was felt that silver buffer layer may not withstand temperatures higher than 950 °C. The sintering time of these films was varied for different films between 30 and 120 min, with a view to examining the formation of the superconducting film and the poisoning (if present) of the film by the substrate. Oxygen flow at a rate of 301 h^{-1} was maintained throughout the heat treatment, after which the film was cooled gradually at a rate of 2 °C min^{-1} or less to a temperature of 300 °C. A sketch of a typical superconducting film is shown in Fig. 1.

Y–Ba–Cu–O films deposited directly on alumina substrates were also subjected to the same process and were also studied, for the sake of comparison, following the same procedure.

3. Results

The critical currents for these films were measured at 77 K using the four-point probe technique shown in Fig. 2, and are given in Table I. From this table it can be seen that the critical currents for the films prepared on the buffer layer are higher by an order of magnitude than those of films deposited directly on alumina substrates. Further, the critical currents are higher in the films with a buffer layer, which are sintered for longer durations. In the case of films without the buffer layer there is a specific time period (30 min) of sintering for which the superconducting film is available on the top; for longer periods of sintering the film loses its superconductivity. This observation has been explained [1] based on the idea that the formation of a superconducting layer proceeds from top to bottom,

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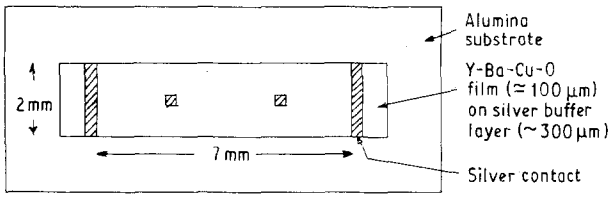

Figure 1 A typical superconducting film prepared on alumina substrate with silver-buffer layer.

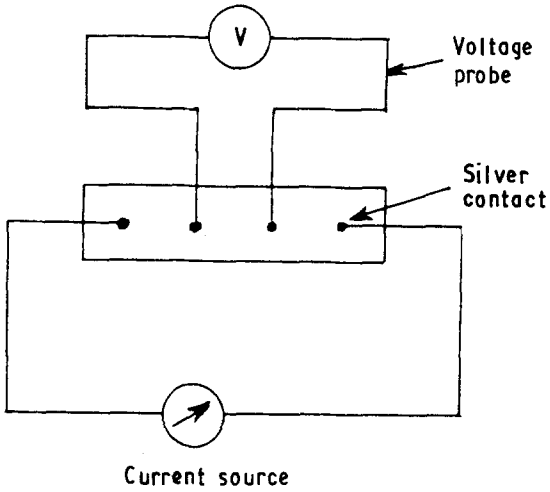

Figure 2 Experimental set-up for measurement of critical currents.

TABLE I Electrical characteristics of Y–Ba–Cu–O films (A) with and (B) without buffer layer

Sample	Sintering period (O_2 atmosphere at 950 °C) (min)	Resistance at room temperature ($K\Omega$)	Critical current at 77 K (μA)
A1	30	1.3	14.2
A2	60	0.3	18.6
A3	120	10.0	23.5
B1	30	10.0	5.0
B2	60	High	–
B3	120	High	–

and the poisoning proceeds from the substrate to the top. Based on this, one would expect the thickness of the superconducting layer to increase with the duration of final sintering, if the buffer layer reduces the poisoning of the film.

To substantiate this view, X-ray diffraction (XRD) patterns were obtained for all the films. Typical diffraction patterns of films prepared for different times at 950 °C, are given in Tables II and III. From these tables, it can be seen that there are many prominent peaks corresponding to Y–Ba–Cu–O on alumina substrates with and without buffer layers sintered for 30 min, indicating that the top layers are superconducting in both cases. From the critical current measurements, it may be seen that the superconducting layers formed are rather thin. When the sintering duration is increased to 60 min and above, a number of prominent peaks corresponding to yttrium–aluminate compounds [8] appear for films directly deposited on alumina substrates, and there are no peaks corresponding to Y–Ba–Cu–O. On the other hand, for films deposited on the silver-buffer layer, there are a large number of peaks corresponding to Y–Ba–Cu–O, and no peaks corresponding to yttrium–aluminate compounds. As the sintering duration is increased, it is likely that the poisoning effect will have reached the surface of the films which are deposited directly on alumina substrates, and the superconductivity may have been destroyed. In the case of films deposited on buffer layers, the poisoning action of the substrate is inhibited and the superconductive layers will have become thicker (as seen from the critical current measurements). Also, the poisoning may be due to the formation of yttrium–aluminate compounds.

TABLE II XRD pattern of samples with silver-buffer layer sintered at 950 °C

Sample and period of sintering	d (nm)	Relative intensity	Structure
A1, 30 min	0.393	0.34	Y–Ba–Cu–O
	0.316	0.67	CuO
	0.239	0.76	Y–Ba–Cu–O
	0.210	0.34	Al_2O_3
	0.120	0.52	Y–Ba–Cu–O
A2, 60 min	0.265	0.47	Y–Ba–Cu–O
	0.245	0.52	CuO
	0.226	0.54	Y–Ba–Cu–O
	0.190	0.49	Y–Ba–Cu–O
	0.159	0.49	Y–Ba–Cu–O
	0.158	0.58	Y–Ba–Cu–O
A3, 120 min	0.310	0.70	CuO
	0.278	0.75	Y–Ba–Cu–O
	0.239	0.70	Y–Ba–Cu–O

TABLE III XRD pattern of sample without the silver-buffer layer sintered at 950 °C

Sample and period of sintering	d (nm)	Relative intensity	Structure
B1, 30 min	0.3735	0.23	Y–Ba–Cu–O
	0.3066	0.25	Y–Ba–Cu–O
	0.2378	1.00	Y_2O_3
	0.2110	0.90	Al_2O_3
	0.1940	0.50	Y–Ba–Cu–O
B2, 60 min	0.370	1.00	$AlYO_3$
	0.367	1.00	$BaCO_3$
	0.263	0.95	$AlYO_3$
	0.232	0.91	$Al_2Y_4O_9$
	0.188	1.00	Y_2O_3
	0.160	1.00	$Al_2Y_4O_9$
B3, 120 min	0.370	1.00	$AlYO_3$
	0.306	1.00	Y_2O_3
	0.274	0.75	$Al_5Y_3O_{12}$

4. Conclusions

We describe a methodology for fabricating high-temperature superconducting components on an alumina substrate, the usual substrate used for fabrica-

ting thick- and thin-film circuits. The method makes use of a silver-buffer layer which can also be printed by film technology. It has been clearly established through the measurement of critical currents and XRD analysis that the poisoning effect of the substrate is almost absent in films prepared on alumina substrates with silver-buffer layers. This methodology will hopefully open up opportunities to use the superconducting electronic components along with conventional components.

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