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Effect of oxide additions on the properties of plasma-sprayed Y–Ba–Cu–O coatings

K A DURGA PRASAD, K C LAHIRY, D MAHESWARA REDDY, S C MOHAN, S RAJENDRA KUMAR, N RAMADASS, S RAVICHANDRAN, R SOMASUNDARAM, G SWAMINATHAN and K VENUGOPAL

Corporate Research and Development, Bharat Heavy Electricals Limited, Hyderabad 500 593, India

Abstract. Plasma-spraying is a potential technique for forming flexible tapes from the brittle high T_c oxides. It is possible to obtain superconducting $YBa_2Cu_3O_x$ coatings by a suitable heat-treatment after spraying. In an effort to improve the critical current densities of the coatings, the effect of additions of Ag_2O, Bi_2O_3 and SnO_2 to the $YBa_2Cu_3O_x$ powder used for spraying was studied. The maximum J_c value of 75 A/cm^2 was obtained for the sample doped with 5% SnO_2.

Keywords. YBaCuO system; plasma spray; critical current density; additives

1. Introduction

Plasma spraying is a viable technique for production of flexible tapes of high temperature ceramic superconductors. There have been several attempts in this direction (Kirkland *et al* 1987; Cuomo *et al* 1987; Karthikeyan *et al* 1988; Konaka *et al* 1988). A common feature of these studies is the necessity of a suitable heat treatment cycle for recovery of superconducting properties in the plasma-sprayed coatings. Although superconducting coatings have been obtained, the reported values of critical current densities have been low. The effect of doping the $YBa_2Cu_3O_x$ (1–2–3) powder with oxides such as Ag_2O, Bi_2O_3 and SnO_2 on the critical current densities (J_c) of the plasma-sprayed and heat-treated coatings has been studied. The essential consideration for additions of these oxides was the possibility of improved intergrain contact, thereby increasing the J_c.

2. Experimental

The powder used for spraying was prepared as follows: Stoichiometric quantities of Y_2O_3, $BaCO_3$ and CuO were mixed thoroughly and calcined at 900°C for 24 h followed by cooling at 50°C/h in air. This operation was performed thrice with intermediate grindings. The powder was prepared in batches of 500 g. The size fraction -170, $+320$ mesh was selected for further processing. This powder was mixed separately with 5% Ag_2O, 5% Bi_2O_3 and 5% SnO_2 in a planetary ball mill.

Stainless steel (grade 304) strips (size 5 cm × 1 cm) were used as substrates which were degreased, grit-blasted and given a bond coat of silver (thickness 100 μ) by the wire-spray technique. The bond coat was essential to obtain adherent films of the superconducting oxides and to prevent their reaction with the substrate.

The superconductor powder thus prepared was then sprayed on to the substrate using a Bay State abrasive gun at a power level of 18 kW. The powder was fed internally and argon was used as the plasma and powder-carrier gas. The deposited coatings were 100 μ thick. The samples, after spraying, were immediately transferred to a tubular furnace whose temperature was maintained at 600°C and allowed to cool slowly. They were subsequently heat-treated at 900°C for 5 h in O_2 atmosphere followed by slow-cooling at 50°C/h with intermediate holds at 700°C, 600°C and 400°C for 1 h, 1 h and 3 h respectively. This optimum cycle follows the work of Venugopal *et al* (1989).

The structure of the powder and the sprayed coatings before and after heat treatment was determined by X-ray diffraction using a cobalt anode X-ray source tube. The superconducting transition temperature (T_c) and critical current density (J_c) were measured using the conventional dc four-probe technique. The samples were given a top coat of silver and heated to 500°C followed by slow-cooling in oxygen prior to electrical measurements. This was done to passivate the superconducting coatings against atmospheric attack and to improve the electrical contacts.

3. Results and discussion

The 1–2–3 powder used for spraying was found to be single-phase orthorhombic $YBa_2Cu_3O_x$ according to the X-ray diffraction pattern. The coating in the as-sprayed condition was poorly crystalline. The heat-treated samples showed a predominantly orthorhombic 1–2–3 structure.

All samples showed a superconducting transition temperature of about 84 K. The critical current densities of the samples are shown in table 1. While addition of Bi_2O_3 and Ag_2O reduced the J_c when compared to the undoped sample, the addition of SnO_2 considerably improved J_c.

4. Conclusion

It is found possible to improve the critical current density of plasma-sprayed YBaCuO coatings using suitable additives. Further investigations on the effect of additive concentration on J_c with a view to improving the same and the reasons for the reduction in J_c with the additives of 5% Ag_2O and Bi_2O_3 are under progress.

Table 1. J_c values of sprayed coatings heat-treated at 900°C for 5 hours.

Powder mixture	J_c (A/cm^2)
1–2–3	55
1–2–3 + 5% Ag_2O	15
1–2–3 + 5% Bi_2O_3	32
1–2–3 + 5% SnO_2	75

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