YBCO HTSC BARS FOR kA RANGE CURRENT LEADS

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Abstract

The potential of YBCO superconductors for the development of current leads has been hindered by the difficulties in the fabrication of long single domain bars where the critical current density can be much higher than the BSCCO counterpart. We have recently shown that through the use of additives, such as CeO_2 [1], self sustained vertical bars can be directionally solidified and very long (8-10 cm) single domains can be fabricated with cross sections up to 0.1 cm^2. In this work we show that this technique can be improved to obtain bars up to 0.4 cm^2 able to carry a current higher than 2500 A measured in pulsed mode allowing the fabrication of kA range current leads for applications in current transmission to High Current Superconductor Magnets. Quality factors of these bars such as homogeneity, critical current, thermal conductivity, dependence of the critical current on the magnetic field and resistance of ohmic contacts are evaluated..

1 INTRODUCTION

The HTSC capability to transport electric current without any energetic dissipation, together its low thermal conductivity, suggest the application of HTSC for high current transport to low temperature SC devices such as magnets [2].The use of HTSC bars as intermediate current leads which link the low temperature device with the conventional metallic current leads at the intermediate boiling temperature of nitrogen, allows the benefit of an important lowering of the helium coolant consumption. In fact, this lowering of the coolant power requirements allows the use of closed cycle cryogenerators, instead the classical liquid helium system, in low temperature magnets for medical or research applications [3].

YBCO melt textured bars are a valuable alternative because its high critical current density which can arise values as high as 20kA/cm^2 , at 77K and in self-field condition, remaining at an important level when an external magnetic field is applied as is necessary when working in a magnetic environment.

In this work, we expose the features of the 1:2:3-2:2:1 composite YBCO bars made in our laboratories by a directional solidification methodology.

2 SYNTHESIS

1:2:3-2:1:1. powdered precursors are thoroughly mixed by milling and shaped to a cylinder by pressing. The bar so obtained is previously sintered at 900 ^{0}C and suspended in a vertical tubular furnace according to a vertical Bridgman-like configuration [4]. The bar, in the isothermal region of the furnace, is partially melted at 1050^{0}C and dragged up at a speed adjustable between 1 and 4 mm/h. The sample so dragged solidifies when the upper temperature gradient, at the end of the furnace, is trespassed. After directional solidification, the metallic contacts are implanted and the bars are subjected at a temperature sequence from 900^{o}C to room temperature in a oxygen atmosphere.

Bars of diameters between 3 and 7 mm have been obtained by this procedure and single domain regions of 10 cm in length, typically, have been observed.

3 STRUCTURE

We can observe by polarised light microscopy three clearly differentiated regions in the bar as is shown in the sketch of figure 1. A first region where polinucleation phenomena take place, giving a multidomain structure with large angle intergrain boundaries. This first region of competition between several growing directions progressively ends in a maximum of 2 cm in length arising a single domain region in which the ab plane of the crystal is typically tilted 45^o respect to the bar axis. This second region extends over more than 10 cm and corresponds with the length of the bars for current lead application. The excess of 2:1:1 phase and other impurities segregated during the crystallisation are dragged to the end of the bar by the solidification front giving arise a third region where the single domain structure disappears.

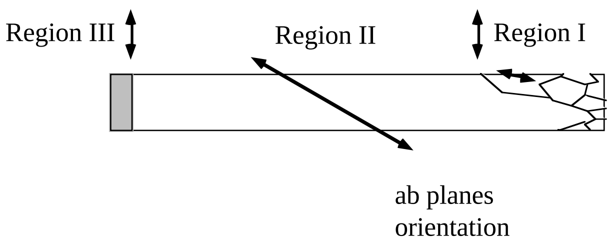

Figure 1. Domain structure of a bar. The single domain region II extends typically over 10 cm.

A characteristique of the single domain region is the appearance of cracks parallel to the ab plane [5]. This structure, which is a limitation of the effective cross section available to the current transport, does not reduce, in fact, the features of the material for current leads applications because the thermal effective path is also reduced maintaining the ratio between the current and the heat flux carried to the cool point of the bar. This structure, however, has an acceptable mechanical resistance because the presence of the 2:1:1 phase which not only contributes to the creation of pinning centers but stops the growing of the cracks.

4 INDUCTIVE CRITICAL CURRENT

Critical currents have been deduced from magnetisation measurements performed by a Quantum Design SQUID Magnetometer.

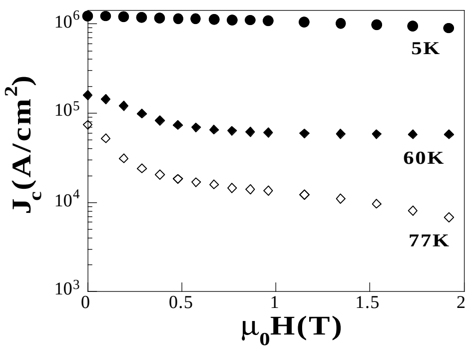

Fig 2. Inductive critical current measured in the ab plane as a function of the applied magnetic field. The measures were performed at 77K, 60K and 5 K

Fig 2 shows the behaviour of the critical current at several temperatures as a function of the applied magnetic Field H. In the zero-field condition the value of the critical current density in contrast with the other superconductor materials involved in the fabrication of bars for Current Leads applications the critical current density maintains a value as high as 10^4 A/cm^2 at a field strength of 1T.

5 TRANSPORT

5.1 Critical Currents

Critical current in bars with 3 mm in diameter has been measured in a four probe configuration by applying current pulses which can arise values as high as 2.5kA during a time of 100µs. The voltage drop is measured when the derivative dI/dt is zero avoiding the inductive component. As we can see in figure 3, a critical current of 2 10^4 A/cm^2 is arisen. This high value shows a good connectivity along de bar although the presence of cracks so signalling that the effective paths correspond to more than the 20% of the whole cross section.

Bars of 7 mm in diameter does not show any measurable resistive voltage drop when subjected to electrical discharges up to 2.5kA thus signalling that the critical value of current is higher than 6.5 kA/cm^2.

Bars of 7 mm in diameter have been also tested by applying stationary current up to 800 A in continuos regime. No voltage drop in the bars has been observed thus indicating that the critical current is higher than this value.

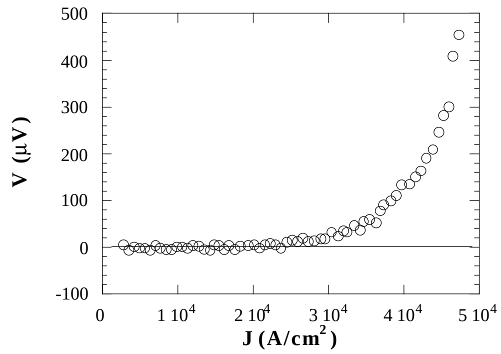

Fig 3. Typical V(J) curve for a 1:2:3/2:1:1 YBCObar measured by current discharging. The critical current density is about 2 10^4 A/cm^2

Quenching when currents as high as 800A are flowing through the sample, activated by an external coil which covers the bar has been performed. The bars supports repetitive quenching and no degradation has been observed.

5.2 Metallic contacts

Contacts have been performed in two ways

- By painting paths with silver-epoxy paste and then heating in oxygen flow up to 900^{o}C and cooling down at a rate of 0.3^{o}C/min.
- By immersion of the end of the bar in melted silver at nearly the melting temperature and then oxygenating the YBCO bar.

Contacts with low temperature solder are fixed to the silver paths allowing an easy connection to the system .

The specific resistance obtained by the two procedures differ in a order of magnitude (see table I) but both are useful in the test process allowing contact resistance in the µΩ range.

Temperature	**Silver-epoxy**	**Melted silver**
77K	7µΩ/cm^2	0.28µΩ/cm^2
4.7K	-	10nΩ/cm^2

Table I . Contact resistance

5.3 Thermal conductivity

Thermal conductivity has been estimated in the range of room temperature and boiling nitrogen temperature by measuring the difference of temperature between two points of the bar during cooling a cooling process in which an end of the bar is linked to the cool point and the other end is heated by means of a resistor. The thermal conductivity (k) so estimated is below 0.5 W K $^{-1}$ m^{-1} in the interval of temperatures between 20K and 150 K. With this value of the conductivity the bars allows a ratio k/ J_c =2.5 10^{-9} W m A^{-1} K^{-1} .

6 TRAPPED FIELD ANALYSIS

In order to stablish a control of the homogeneity of the bars, they are subjected to a field cooled process in a field of 200G. The field remanence is analysed by exploration of the surface of the bar by means of a Hall probe [6]. The remanent field is very sensitive to the absence of connectivity in a part of the sample. Figure 4 shows the result of this analysis over a sample of 4 cm in length. A defect in the bar is observed in the position 27 mm. This defect stops de current flow and the overall critical current drastically vanishes

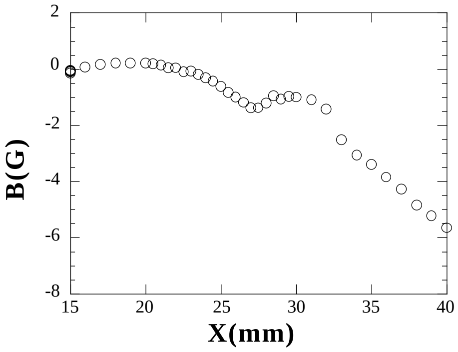

Figure 4. Distribution of the surface values of the trapped field in a bar of 4 cm in length. At position y=27 mm a defect is present which can affect drastically the overall critical current

7 CONCLUSIONS

In conclusion, we have shown that bars of 1:2:3-2:1:1 YBCO composite are an alternative to be considered for current leads when a soft heat linkage is necessary. The high critical current values in magnetic environments allows the use of the YBCO HTSC bars in magnets engineering.

8 ACKNOWLEDGEMENTS

This work has been supported by MIDAS program (89-3789), CICYT (MAT91-0742) and CEE-SCIENCE (SCI-0389-M(A))

REFERENCES

[1] S.Piñol, F.Sandiumenge, B.Martinez, N.Vilalta, X.Granados,V.Gomis, F.Galante, J.Fontcuberta and X.Obradors, IEEE Trans. on Appl. Supercond. (in press)

[2] T.Kuriyama, M.Urata, T.Yazawa, K.Yamamoto, Y.Ohtani, K.Koyanagi, T.Masegi, Y.Yamada, S.Nomura, H.Maeda, H.Nagakome and O.Horigami, Cryogenics, **34**, 643 (1994)

[3] E.T.Laskaris, K.G.Herd and B.Dorri,Cryogenics, **34**, 635 (1994)

[4] S.Piñol, V.Gomis, B.Martinez, A.Labarta, J.Fontcuberta and X.Obradors, J. Alloys and Compounds **195**, 11 (1993)

[5] X.Obradors, B.Martinez, F.Sandiumenge, S.Piñol, J.Fontcuberta, V.Gomis, X.Granados, N.Vilalta and J.Mora, Fourth Euro Ceramics, 6, 173, (1995)

[6] H.G. Kürschner, B.Lehndorff,, H.Piel, International Conference on Magnetically Levitated Systems,, Bremen, November (1995)