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Electrical and mechanical properties of Bi-2223/Ag tapes made by TIRT technique

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Abstract

Multi-core Bi-2223/Ag tapes with various number of filaments (21–162), different filament architecture and their changing orientation to the tape plane have been made by the tape-in-rectangular tube (TIRT) process. The transport current properties of TIRT tape samples with "parallel" and "perpendicular" filaments have been measured. The transversal I_c distribution obtained by spatially resolved transport measurements ("magnetic knife") measurement illustrates that filament quality of TIRT tapes is better at the tape edges as in its centre. The I_c degradation due to bending shows a different behaviour for parallel and perpendicular filaments which is attributed to the difference in filament density and crack propagation.

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Keywords: TIRT Bi-2223/Ag tapes; I_c anisotropy; I_c distribution; I_c degradation

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1. Introduction

The tape-in-rectangular tube (TIRT) process is based on the deformation of BSCCO/Ag composites assembled from pre-deformed single-core tapes inserted in a rectangular Ag (Ag-alloy) tube. It allows the preparation of a multifilamentary Bi-2223/Ag tape with various filament architecture and different filament orientations [1]. This usually leads to high filament aspect ratio for filaments, which are parallel with the flat side of the tape, or to low aspect ratio and not straight (bent) filament shapes for the perpendicular arrangement. The aim of this contribution is to show the main electrical and electro-mechanical differences for TIRT tapes with parallel and perpendicular filaments.

2. Experimental

The Bi-2223/Ag tape having filaments in one or several columns arrangement has been made by TIRT process [1]. Three configurations having: 21 perpendicular filaments (tape A), 60 parallel filaments placed in three columns (tape B) and a combination of these two tapes (162 filament tape C) are shown in Fig. 1. The transport critical currents in an external magnetic field of magnitude $B = 0$–1 T and for various B orientations

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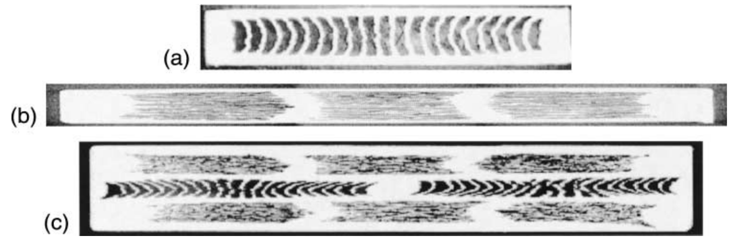

Fig. 1. The cross-sections of TIRT Bi-2223/Ag tapes with perpendicular and parallel filaments.

(between parallel and perpendicular) at constant field ($B = 0.5$ T) are measured by a four point probe method, at 77 K. The magnetic profiling methods ("magnetic knife") based on the movement of the tested Bi-2223/Ag sample through a sharp perpendicular field gradient (from +0.2 to −0.2 T) and subsequent $V(I)$-curve measurement at each position is used [2]. By passing the tape through the field gradient, a profile of the current distribution inside the tape is obtained. The actual critical current $I_c(x_0)$, which is measured when the tape is at a certain position x_0 with respect to the position of zero magnetic field, is given by the convolution integral [2]. By deconvolving the measured current profile $I_c(x_0)$ with respect to the resolution function $g(B(x - x_0))$, one obtains the product $J_{c0}(x)t(x)$. If the thickness $t(x)$ is known, e.g. from a micrograph of the cross-section of the tape, it is possible to determine $J_{c0}(x)$.

The sensitivity of TIRT tapes to a mechanical stress is tested by bending at 77 K, which allows measuring the I_c changes at continually decreased or increased bending diameter at the same element of tape [3]. The tested tapes (A and B) were heat treated on the ceramic former of diameter 40 mm. During the stressing, the bending diameter was decreased up to 15 mm and then back to 40 mm.

3. Results and discussion

Fig. 2 shows the angular dependencies of critical current ($I_c(\alpha)$ curves) measured at 77 K and $B = 0.5$ T for tapes A, B and C. As it is shown there, the maximum current of tape A is measured when the external field is perpendicular to the tape surface ($\alpha = 0$) and minimum for parallel field,

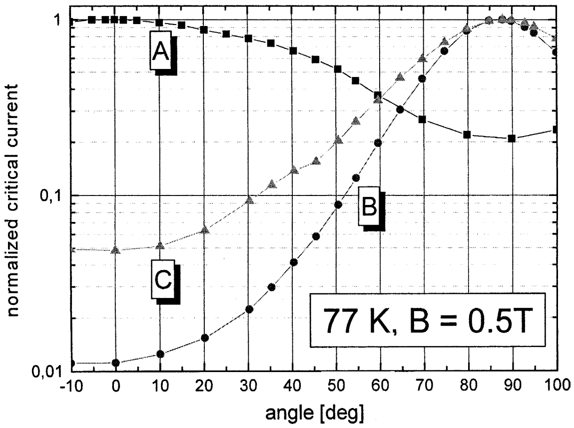

Fig. 2. The angular dependencies of the normalized critical current in TIRT tapes with various filament orientation.

$\alpha = 90°$ (opposite to usual $I_c(\alpha)$, e.g. tape B). The angular dependencies of tapes B and C show how the angular dependencies and how the total anisotropy ratio decreases by a combined filament orientation. On the other hand, the decrease in I_c-anisotropy leads to a lower J_c value [1]. Although the absolute value of overall current density for tape A (having perpendicular filaments) is quite low, the $J_{ov}(B\|ab)$ and $J_{ov}(B\|c)$ curves of tape A cross the curve $J_{ov}(B\|c)$ of tape B at 0.23 and 0.35 T, respectively. This gives a chance to use the tape with perpendicular filaments for outer part of a superconducting coil in order to reduce the effect of the radial field component.

Fig. 3 shows the typical spatial transport current distributions for Bi-2223/Ag tapes with parallel filaments arranged in three columns. While for the usual multifilamentary Bi-2223/Ag tape, the highest currents are transported by the central filaments [2,4], the TIRT tapes behaves similarly as

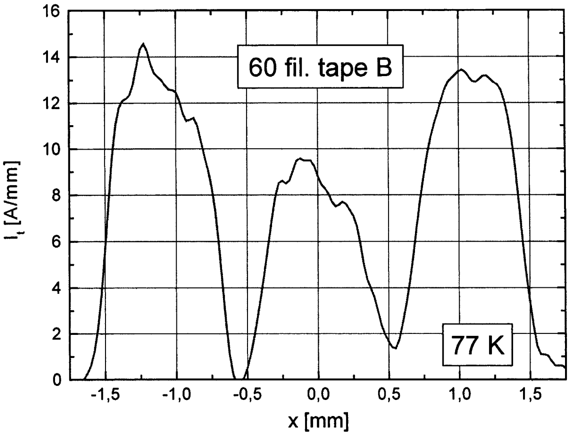

Fig. 3. Spatial I_c distribution in the width of the 60 parallel filament tape obtained by magnetic profiling method.

single core tapes with the highest current densities at the tape edges and the lowest one in its centre. This can be explained by the more optimal filament deformation (widening) in outer columns during the intermediate deformation by eccentric rolling (ER). ER induces better texture and allows well grain connections in the outer filament columns, while it leads to a higher ceramic density and a less optimal texture in the central one.

The plot of the normalized critical current versus the bending diameter is in Fig. 4. Though tape A (perpendicular filaments) is nearly two times thicker than tape B (0.475–0.248 mm), only a small $I_c(d)$ difference is measured at decreasing bending diameter (40–15 mm) for tapes A and B. This is attributed to the lower density of perpendicular filaments, which are less deformed as the parallel filaments. During the bending, the density of inner part of perpendicular filaments is probably initially increased without apparent I_c degradation, while for dense and thin parallel filaments the grains connection damage occurs. The superconducting tape is considered as a composite with brittle ceramic filaments, which are not breaking uniformly. The cracks distribution is starting at the weakest point which is usually at outer filament. Therefore, in the case of tape B, a much easier cracks distribution in outer filaments layer will lead to the beginning of a rapid I_c degradation at $\varepsilon_b = 0.21\%$, while for tape A, where only outer edges of perpendicular filaments are initially damaged, this occurs at $\varepsilon_b = 0.4\%$.

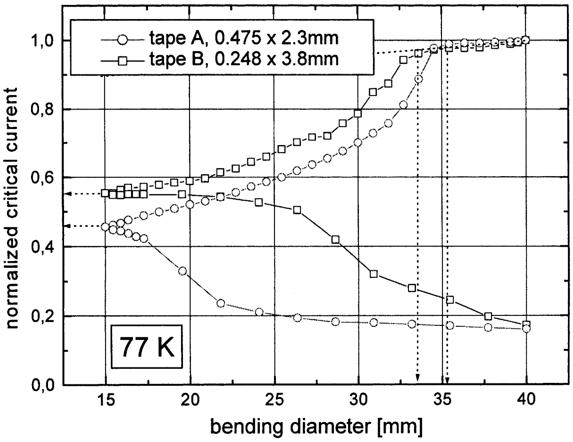

Fig. 4. Sensitivity of parallel and perpendicular filaments to bending stress applied at 77 K by decreasing and increasing of bending diameter from 40 to 15 mm and back to 40 mm.

4. Conclusions

The main transport properties of TIRT Bi-2223/Ag tapes with parallel and perpendicular filaments have been measured. It is shown, that the I_c anisotropy can be decreased apparently by the perpendicular filament architecture. This gives a chance to reduce the effect of the radial field component in a superconducting winding. On the other hand, perpendicular filaments with low aspect ratio have a considerable lower J_c.

Concerning to the transport current distribution of TIRT tapes, they behave similarly as single core tapes (opposite to usual multifilamentary Bi-2223/Ag) with the highest current densities at the tape edges and the lowest one in its centre. The parallel filaments are more sensitive to bending stress than perpendicular ones, which is probably caused by a different filaments density and by not so drastic cracks distribution through the perpendicular filaments.

Acknowledgements

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