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The Current Distribution in Bi-2223/Ag HTS Conductors: Comparing Hall Probe and Magnetic Knife

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Abstract. We analyzed the current distribution in three Bi-2223/Ag tapes with different filament lay-out, comparing the results of magnetic knife and Hall probe experiments. Detailed knowledge of the current distribution can be useful for the diagnostics of HTS conductors. The lateral current distribution was measured with the non-destructive magnetic knife technique and used to calculate the corresponding magnetic field profile above the tape. These calculated profiles were then compared to those actually measured by a Hall probe. Additionally, the Hall probe data were also compared with "ideal" field profiles, assuming uniform current flow across the tapes. This assumption is often used in measurement interpretation. The Hall probe - and magnetic knife data correspond very well, but deviate significantly from the ideal profiles. Further analysis of the current distribution shows that this deviation is mainly due to suppression of the critical current density at the tape edges.

1. Introduction

The main goal of this paper is to analyze the real current distribution in the HTS conductors. The results obtained on Bi-2223/Ag tapes carrying a transport current are presented here. Two different experiments for local current distribution determination were used; a direct technique for local lateral current distribution determination, the magnetic knife (MK) [1, 2] and an indirect one, the Hall Probe Mapping System (HPMS) [2, 3]. The magnetic locally suppresses superconductivity by applying a magnetic field profile and is suitable mostly for samples with strong dependence of the critical current I_c on applied magnetic field. The Hall probe technique provides indirect information on critical current distribution, by measuring the magnetic self-field profile across the tape. Both techniques have advantages and drawbacks, but by comparing the results an extra sight is gained. Such comparison can not be done directly, of course, since the MK yields current profiles and the HPMS magnetic field profiles. Nevertheless, a meaningful comparison can be made in two ways. The first is to compare the current profile, obtained from the HPMS data by solving inverse problem, with the current profile provided by the MK. In this paper we present the reverse way, we calculate the magnetic field profile from measured current profile. Unlike the inverse method, this calculation is direct and trouble-free. We show how the results of the two experiments correspond and compare them with critical state model predictions.

2. Experimental

The MK uses the strong suppression of the critical current I_c in a perpendicular magnetic field B_z to measure critical current only in a narrow channel of a Bi-2223/Ag tape. It applies a magnetic field profile which is nearly constant over the whole tape width, except for a narrow channel at $x = x_0$ where the polarity of the field is sharply reversed. The sample is shifted through the magnetic field profile in steps of 50 µm, while for each position I_c is determined using the standard four-probe technique. The critical current I_c, defined with a voltage criterion of 10^{-4} V m^{-1}, is measured at 77 K in liquid nitrogen. The total sample length is 50 mm. The second, contact-less, HPMS technique is widely used for characterization of magnetic fields in the vicinity of superconducting tapes. HPMS measures the field component perpendicular to the broad tape face (B_z) at desired spatial points. The active area of the HP sensor is typically 50 µm x 50 µm and its sensitivity of the order 100 mV T^{-1}.

The samples studied in this work are all Bi-2223 Ag-sheathed tapes. Figures 1 - 3 show cross-sectional micrographs of the multifilament samples while their dimensions are given in Table 1.

Table 1.

Sample	Size [mm]	No. of filaments	I_c [A]	Note
1	3.5 x 50	55	54	high density of filaments, filamentary bridging, not twisted
2	4.05 x 50	37	16	very low fill. factor, not bridged, not twisted
3	2.65 x 50	16	17	16 filaments in 2 columns 2 x 8, not twisted

Figure 1. Sample 1, cross section micrograph.

Figure 2. Sample 2, cross section micrograph.

Figure 3. Sample 3, cross section micrograph.

3. Results and discussion

The lateral current profiles of samples 1-3 measured with the MK are shown in figure 4. The profiles across the sample are expressed in terms of sheet current, which means the critical current per unit length $I_{shx} = I_{cx}/w_x$. From these current profiles, the corresponding magnetic field profiles were calculated using equation (1), which assumes the current to flow in an infinitely long thin strip whose thickness is negligibly small in comparison with its other dimensions [4].

$$H_{zi} = -\frac{I}{2\pi w}\ln\left(\frac{r_1}{r_2}\right) \qquad (1)$$

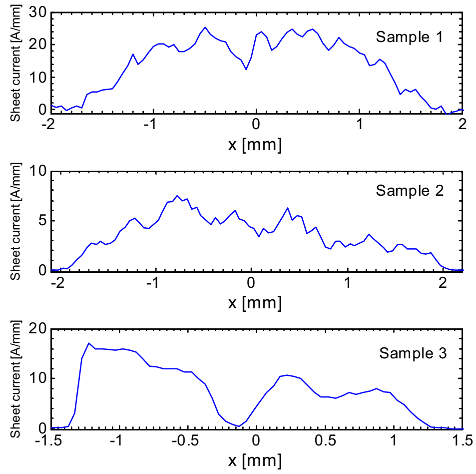

Figure 4. Local sheet current in various tapes Bi-2223/Ag.

The measured current profiles consist of approximately 80 spatial points each (the tapes are about 4mm wide and experimental step is 50 µm). Each point of the magnetic field profile is calculated as a sum of contributions of 80 sub-strips each having a width of 50 µm, corresponding to the spatial points of the MK current profile, figure 5. We measured the magnetic self-field profiles of the samples at $I = I_c$ with the HPMS. In figures 6-8, the measured profiles are compared with the ones calculated from the MK data and with model profiles based on the assumption that the current is uniformly distributed across the tapes. The experimental field profiles measured with the HPMS correspond very well with the local current distributions measured using the MK. The best accordance shows sample 2, figure 7. On the contrary, the model profiles are quite different from the experimental data, indicating that the real current distributions in tape are not uniform, but are closer to the results from the MK measurements. Figure 9 compares the current profiles measured with the MK (represented by histograms) with the relative spatial density of superconductor across the tape. The latter quantity is obtained from cross-sectional micrographs of the tapes, assuming that each image pixel contains the same amount of superconducting material.

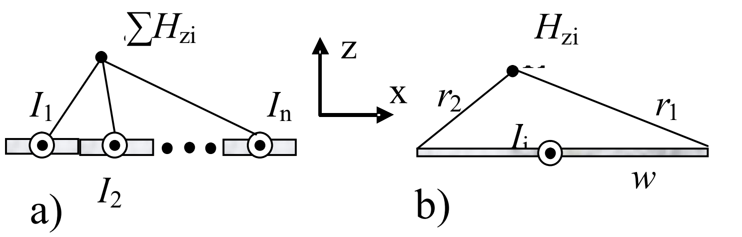

Figure 5. Drawing explaining the expression (1)
a) sum of all sub-strips' contributions, b) one element - thin strip

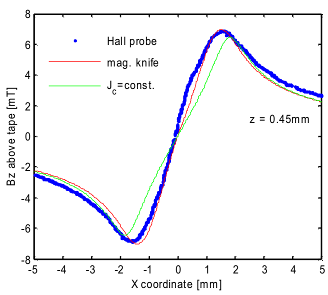

Figure 6. Sample 1, comparison of profiles: Hall probe, calculation based on MK and model with constant J_c distribution across the tape

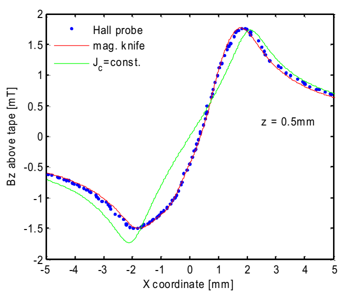

Figure 7. Sample 2, comparison of profiles: Hall probe, calculation based on MK and model with constant J_c distribution across the tape

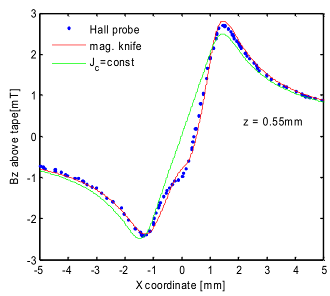

Figure 8. Sample 3, comparison of profiles: Hall probe, calculation based on MK and model with constant J_c distribution across the tape

Comparing the histograms with these density profiles, we can estimate areas with higher and lower critical current density in the tape. Higher values of J_c are found in the central parts, while J_c is lowered at the edges of tapes.

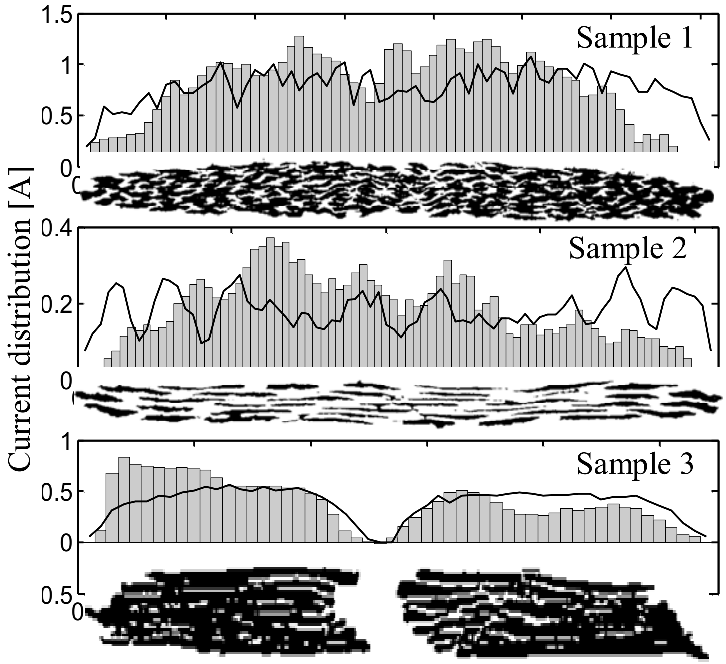

Figure 9. Histograms correspond to local current distributions measured by the MK with spatial step of 50 μm; black curves correspond to the spatial densities of superconductor across the samples obtained from the cross section micrograph. Micrographs are stretched vertically.

4. Conclusions

Measurements of the lateral current distribution in Bi-2223/Ag tapes with various filament lay-out, made using the magnetic knife technique, correspond very well with self-field profile measurements obtained by with a Hall probe system. The data show that models, assuming a uniform current distribution across the tapes, yield results which do not correspond to the experiments. The deviations are mainly due to a significant suppression of the critical current density at edges of samples.

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References

[1] ten Haken B, van Eck H J N, ten Kate H H J 2000 *Physica C* **334** 163-167

[2] Kovac P, Masti M, Lehtonen J, Kopera L, Kawano K, Abell S, Metz B, Dhalle M 2005 *Supercond. Sci. Technol.* **18** 1-8

[3] Polak M, Majoros M, Kvitkovic J, Kottman P, Kovac P, Melısek T 1994 *Cryogenics* **34** 805

[4] Kulda J Magnetické pole v silnoproudé elektrotechnice. Academia, Praha 1974