Characterization of individual filaments extracted from a Bi-2223/Ag tape

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Summary

Previous studies by Strano et al suggest that there is a significant variation from filament to filament in a multifilament superconducting Bi-2223/Ag tape. We are investigating this variation for a high J_c tape and also we are studying the positional variation of the properties within one filament.

For this study, we extracted all the filaments from a specially prepared high-quality tape having J_c(0T, 77K) = 45 kA/cm² with 19 disconnected filaments. By attaching current leads and voltage taps to the tape, we are able to measure electrical properties on a scale of 200-300 μm. By using a Focused Ion Beam (FIB) technique, we can make local cuts within a filament with a precision of about 1 μm, selecting ~40x40 μm areas for characterization.

The experiments show a large variation in filament properties. The conductivity of a filament at room temperature is proportional to its critical current density J_c at 77K (self-field) and filaments with a higher transition temperature T_c do also show a higher J_c. There is also a variation in the in-field behavior of the filaments. Filaments from the center of the tape are thinner and have a larger aspect ratio (and thus a larger silver-filament interface) and have better properties than filaments from the edges.

We also observed variations in the local critical current density along the filament. Along length scales of ~300 μm we saw variations in J_c up to 30%. The FIB results show that the outer (thinner) part of a filament has better properties than the thicker part, especially in a magnetic field.

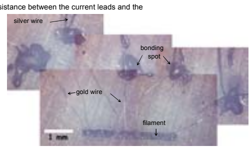
Experimental details

A specially prepared (R. Parrella AMSC) 19 filament Bi-2223/Ag tape with low filling factor (11%) and unbridged filaments was used in order to ease the extraction of all the filaments from the tape.

The tape is approximately 2.2 x 0.15 mm². The critical current density (77K, self-field) is 45 kA/cm². The filaments are 200-400 μm wide and 10~20 μm thick with aspect ratios of 10-40. The area of the cross section of the filaments is 1700 μm².

Several mm long filaments are extracted by dissolving the silver sheath in a NH_4OH / H_2O_2 solution and their surface cleaned with acetic acid so as to lower the contact resistance between the current leads and the filament.

Filaments are placed on a sapphire substrate. Using silver-epoxy, gold current leads (12.5 μm diameter) are attached to both the top and bottom of each filament to provide a symmetric current feed into the *a-b* planes.



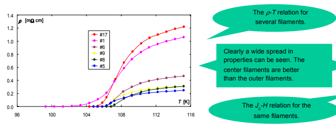
Three voltage taps enable two sections of the filament to be measured with spacing of 200-300 μm.

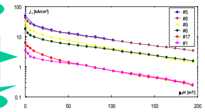
The gold current leads and voltage taps are connected to 50 μm silver wires, which connect to the external circuit.

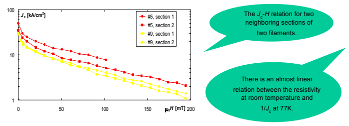
Both resistivity-temperature and voltage-current characterizations were performed. The *ρ-T* measurements were performed in vacuum. The *V-I* measurements were performed in liquid nitrogen, in order to minimize the possibility of a burn-out. An electric field criterion of 1 μV/cm is used.

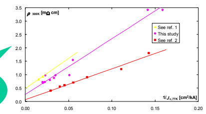
Cuts in the filament were made in two steps. The first step is done by a laser-cutter with a precision of ~10μm. The edge of the cut that defines the current path is made by a Focused Ion Beam (FIB) with a precision of about 1μm.

Results









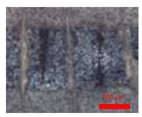
Summary of the data	#1	#5	#6	#8	#9	#17
J_c [kA/cm²] @ 0 mT	3.5	50	18	43	30	6.3
J_c [kA/cm²] @ 100 mT	0.7	7.7	3.7	7.6	4.0	0.7
ρ [mΩ cm]	3.0	0.72	1.5	1.0	0.87	3.4
$\mu_0 H_p$ [mT]	91	95	111	115	88	86
T_c [K]	101.0	105.5	105.0	105.5	105.5	104.5

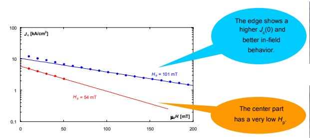
H_p is a measure for the decrease of J_c in field: $J_c \sim e^{-H/H_p}$.

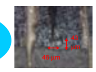
Ref. 1: X.Y. Cai et al: "Thickness Dependence of Jc in Filaments Extracted From High-Jc Ag/Bi2223 MF Tapes", MRS 2000

Ref. 2: G. Grasso et al, Physica C **281** (1997) 271-277 (These are monofilaments)

Variation of properties within one filament







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