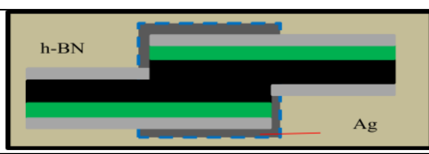
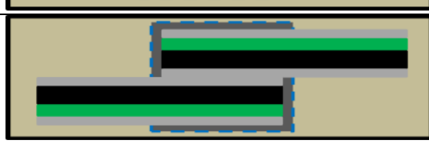
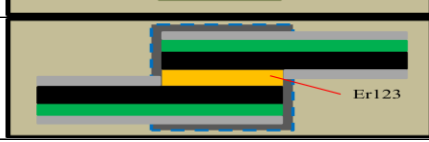
Superconducting Y-123 joints by Spark Plasma Sintering

Abstract: Spark Plasma Sintering (SPS) was applied for fabrication of superconducting joints. Joints were realized between stacked two $Y(Gd)Ba_2Cu_3O_7$ commercial tapes, tape-bulk-tape or bulk-bulk-bulk where the bulk from the middle of the stack was of $ErBa_2Cu_3O_7$. Some of the arrangements and for some processing conditions joints have shown zero resistance below 35K.

To realize persistent magnetic coils generating high magnetic fields, use of superconductors is required. Coated tapes of high temperature superconductor $REBa_2Cu_3O_7$ (123, RE-rare earth elements) are at present suitable candidates delivering high performance at acceptable prices. Their application requires fabrication of superconducting joints [1, 2].

In this work we explored the possibility to use spark plasma sintering (SPS) for the fabrication of joints. Spark plasma sintering is a method that applies a pulsed current on the punches of a mold (usually from graphite as in this work) loaded with the samples to be sintered. Simultaneously on the punches a uniaxial pressure is also applied. The method is flexible ensuring high heating and cooling rates.

Table 1. Samples (S), arrangement, SPS conditions, post-annealing conditions, zero-resistance critical temperature (Tc0).

S	Etching (time, H2O2/HNO3)	arrangement	SPS conditions	Post-annealing	Tc0 (K), observations
Raw tape	-	-	-	-	92.45
A	40s, 2.4/1	-	-	-	92.55
B	100s, 1/2.4	-	-	-	89.45
C	60s, 2.4/1		- Pressed at 20°C at 18KN	-	Sharp transition above 93.45K, it has residual resistance
D	-		400°C/3min/ 18KN	-	Multiple transitions, it has residual resistance
E	60s, 2.4/1		300°C/3min/ 18KN	-	Multiple transitions, above 35.5K
F	-		870°C/3min/ 15KN	470°C/60 h/O_2	Multiple transitions, above 35K
G	60s, 2.4/1		870°C/3min or 850°C/3min/ 15KN	470°C/60 h/O_2	Resistance measurement in progress

In our experiments we used different arrangements as follows: bulk-bulk-bulk, tape-bulk-tape and tape-tape (Table 1). Commercial tapes were of $Y(Gd)Ba_2Cu_3O_7$. The outer bulks of the sandwich-like stacks were of $YBa_2Cu_3O_7$, while the middle ones were of $ErBa_2Cu_3O_7$. Bulks were obtained in the lab. by the solid-state-reaction.

As SPS sintering media hexagonal BN powder was used. The SPS atmosphere was of Ar (0.75 atm). Other processing conditions including post-annealing in oxygen are presented in Table 1.

During preliminary experiments it was found that etching conditions for Ag removal from the surface of the superconducting layer of the tape can influence the quality of the tape (compare samples raw tape, A and B in Table 1 and Fig. 1). It was also found that Ag-cover is useful for a better mechanical strength of the joint.

SPA processing temperatures were from 300 up to 890°C. Pressing at room temperature or heating by SPS at low processing temperatures of 300, 400°C (samples C-E in Table 1, Fig. 1) indicated that joints formed, but they are not metallurgical and, hence, they are not mechanically stable and the reproducibility is low. Samples (e.g. F, Table 1, Fig. 1) fabricated at high temperatures attain zero resistance after post-annealing treatments to introduce oxygen depleted during SPS processing. In such a case, zero resistance was measured below 35K and a metallurgical joint was realized. Therefore, a high SPS-processing temperature (around 830-870°C) followed by post-annealing in oxygen is required and optimization process (sample G, Table 1, Fig. 1) is in progress. Optimization of the pressing pressure during SPS and of annealing conditions is also under investigation.

In summary, presented results are promising and it is of interest to further explore application of SPS for fabrication of superconducting joints.

References

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[2] Y. Park, M. Lee, H. Ann, Y.H. Choi, H. Lee, NPG Asia Materials 6 (2014) e98.

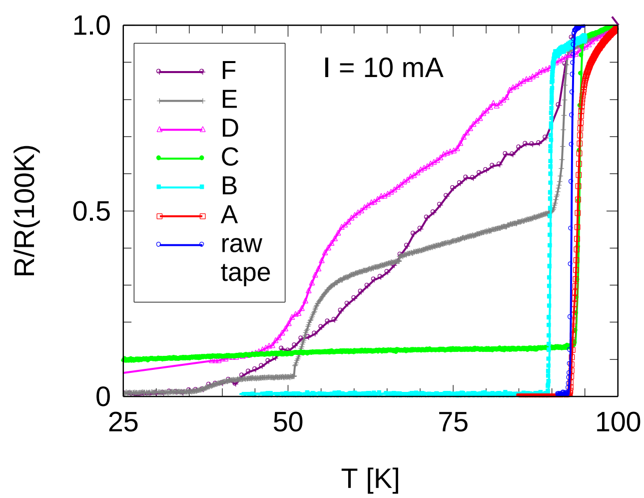

Fig. 1 Reduced resistance versus temperature curves. Sample notation is as in Table 1.

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