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Quantitative Metallographic Analysis of the Effect Of Cooling Rate On Powder-in-Tube Nb_3Sn Superconducting Strand with Al_2O_3 Additions

תיכון "אלון" – רמת השרון
"ALON " HIGH SCHOOL - RAMAT-HASHRON

Introduction

Precise measurements of the superconducting, non-superconducting and stabilizer areas in superconducting composites are important in interpreting their properties. In this study we use a new tool at NHMFL: The LEXT laser scanning confocal microscope can make precise reproducible color measurements because of its LED light source and through-focal imaging, as well as high spatial resolution images with its laser scanning confocal capability.

Hypothesis

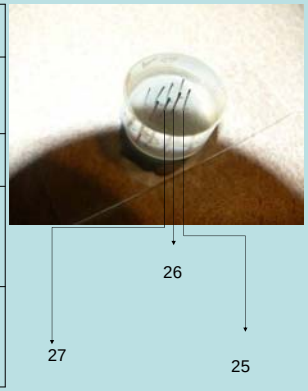
Cooling rate affects the microstructure of the superconductors.

Method

The difference between the two sets of samples was the cooling process. One cooling set was cooled from the reaction heat treatment temperature by air quenching (aq) and the other by was slow cooled (sc). Each of the sets contained 3 different strands (numbered 25, 26, 27) which had different initial powder compositions, as shown in Table 1. Each one of the strands had 18 filaments. The samples were metallographically polished and etched to revealed the different phases.

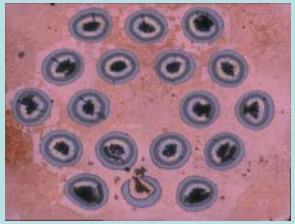
Table 1:Initial Strand Compositions

Core type **25**	Core type **26**	Core type **27**
Cu clad Sn+ 10A/203 **n**	Cu clad Sn+ 10A/203 **g**	Cu clad Sn**Cu**+ 10A/203 **g**
Copper Container	Copper Container	Copper Container
-40 micron **pure Tin** powder	-40 micron **pure Tin** powder	-40 micron **Sn 8w/o Cu SAP** powder
10 v/o Aluminum oxide, **nanopowder**	10 v/o Aluminum oxide, **gamma**	10 v/o Aluminum oxide, **gamma**



Apparatus:
The images were acquired using a High Resolution 3D reflected light Microscopy with an dry objective lens of X100 magnification.

Properties of microscope:
- The Microscopy scan was made by a solid state 408 nm blue laser and a white LED light.
- Fully digital pinhole confocal for light sources
- 120 nm spatial resolution (1/2000 thickness of human hair)
- 10 nm depth resolution
- Digital stage with automated matrix imaging for large area
- 3D imaging and volumetric analysis.



COLOR IMAGE - STRAND NO SC 26

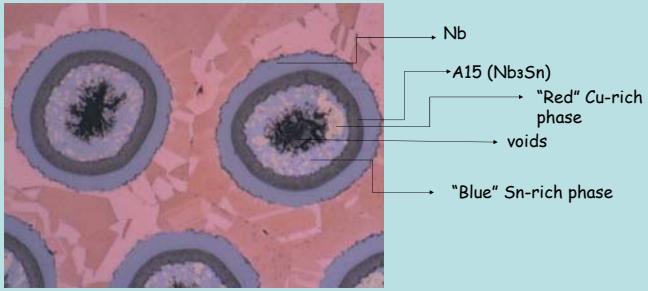
LASER IMAGE - STRAND NO SC 26

The procedure

1. Scanning in objective x100 required tiling the images to get a whole accurate image of each one of the filaments (4x5 image tiles creating ~ 3000x2500 pixel montages).
2. The image montages were analyzed using IMAGE-J software [1]. Additional noise reduction was performed using the GIMP software package.
3. Ratios between each of the average areas of the layers and the whole filament was calculated using a spreadsheet.

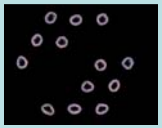
[1] Rasband, W.S., ImageJ, U. S. National Institutes of Health, Bethesda, Maryland, USA, http://rsb.info.nih.gov/ij/, 1997-2007.

The analysis consisted of isolating the layers and measuring the total area of the strand, and the average area of each of the layers in the filaments in the strand. Two phases, distinguished by color ("Blue" and "red") are found in the core of each filament after reaction.

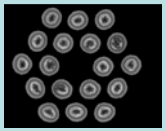


Examples of layers

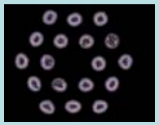
"Red" Copper-rich phase



core phase



filaments



Filaments non-Nb

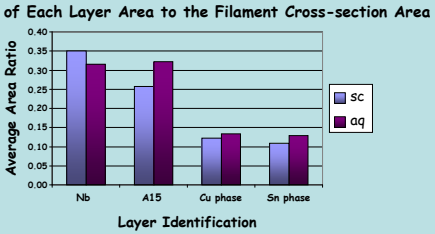
Recommended Reading: Optimization of Internal-Sn Nb_3Sn composites, M. T. Naus, PhD Thesis, UW-Madison 2002

Results

Table 2. Measured ratios of each phase

	25		26		27	
	sc	aq	sc	aq	sc	aq
Nb	0.40	0.39	0.36	0.23	0.29	0.33
A15 (Nb_3Sn)	0.24	0.27	0.24	0.38	0.29	0.32
Cu phase	0.10	0.13	0.08	0.08	0.19	0.19
Sn phase	0.13	0.10	0.13	0.19	0.06	0.09

In the diagram below we present a comparison between the average ratio of the various areas in the 3 strands in the sc sample and the aq sample



Summary

1. After treatment there are only slight differences in Nb areas, red phase and blue phase areas.
2. However there is a significant difference between the A15 (Nb_3Sn) in the samples: It is much bigger in the aq sample, comparing to the sc sample.
3. A further analysis indicates that the most significant difference was found in the 26 strand (gamma Al2O3 without Cu in powder mixture), which had the highest A15 content after reaction after AQ but not SC.

Conclusion

The samples labeled as air quenched had significantly more A15 than the slow cooled samples and the initial starting powder composition influenced the sensitivity of the composite to cooling rate. This data will aid the interpretation of critical current measurements, allowing the calculation of A15 layer critical current density.

Acknowledgments

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