Post-Delamination Structural Investigation of REBCO Superconducting Tape

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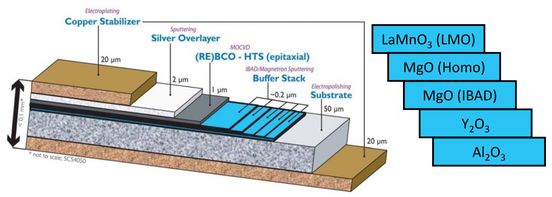
Introduction

- ❖ $YBa_2Cu_3O_7$ (YBCO) is a rare-earth based superconductor that is fabricated as a composite tape. The material has a critical temp. of 93 K, and with the composite structure it can reach up to 400A at 77K, self field.
- ❖ Under certain conditions the composite tape can delaminate, either at an interface or within a layer.
  - ❖ The goal of this study is to analyze and quantify the damage present in peel-tested samples, in order to learn more about the nature of delamination initiation and propagation to increase the effectiveness of this material.

Acknowledgements

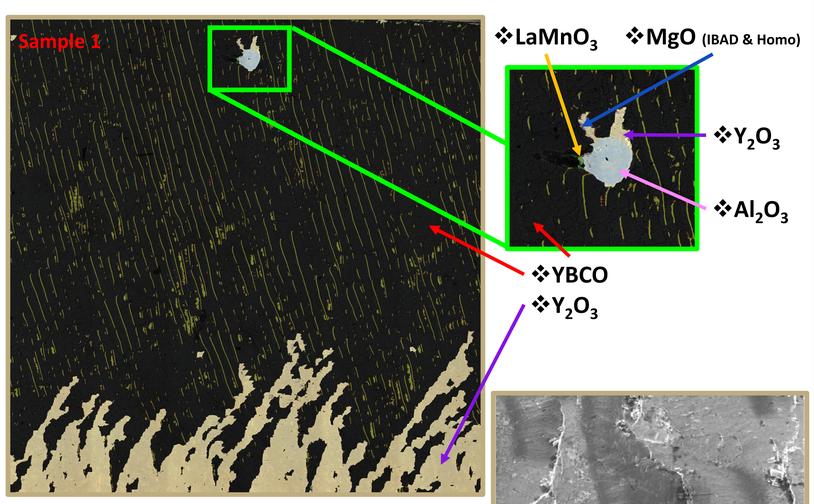
This work was financially supported by the U.S. Department of Energy, Office and High Energy Physics, award DE-FG02-13ER42036, and benefited from the support of the Materials Science & Engineering Center at UW-Eau Claire. This study was supported by the UW-Eau Claire Blugold Fellowship Program which is jointly funded by Differential Tuition and the UWEC Foundation. The authors also thank SuperPower, Inc. for providing the samples under investigation.

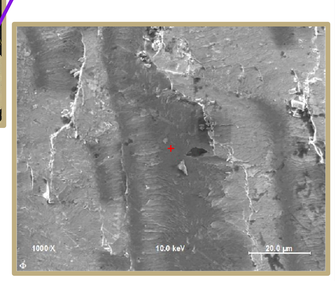
Identification

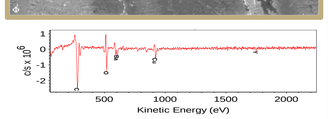


The structure of the tape includes a nickel-based Hastelloy substrate for mechanical strength, 5 buffer stacks (as detailed above) to provide epitaxial crystal growth of the YBCO, a silver capping layer for mechanical protection, and a copper layer for electrical stability.

The samples being used in this study have been peel-tested by SuperPower. This leaves us with two halves of the composite tape, which we are then able to analyze. Our first priority was to identify the different layers in the samples in order to gain an understanding of how the delaminations occur. Using a combination of imaging (SEM and laser confocal microscopy) and chemical identification (EDS supplemented with Auger), we were able to successfully identify all layers in our samples.

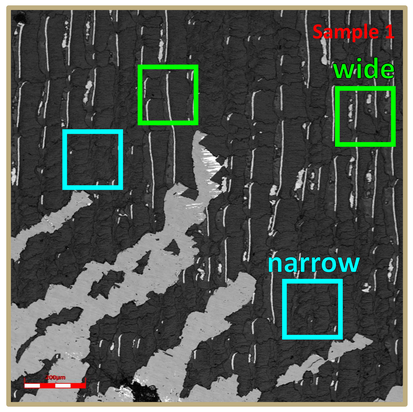


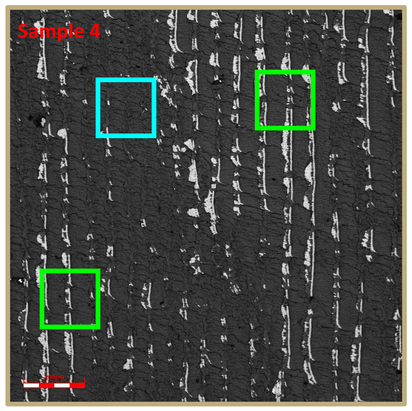




At high magnification and with complementary Auger analysis, we determined that the yellow striations in the YBCO area are not actually a buffer layer as previously thought, but instead a thin layer of retained YBCO. In this case the delamination occurred within the YBCO layer rather than at an interface.

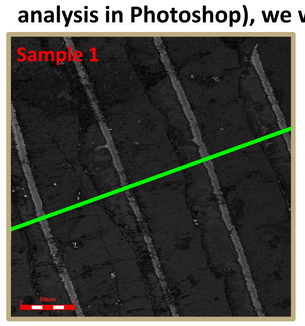
Morphology

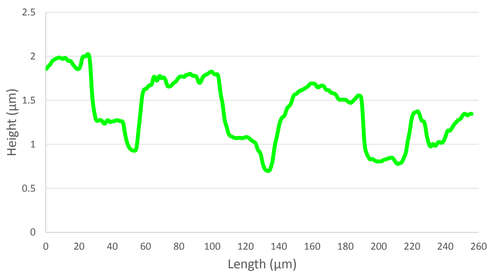




Above are two confocal images taken from our samples. The boxes indicate two different morphology types that are present. The blue boxes indicate 'narrow' ridges, which have a more sporadic shape and have a narrower width compared to the other ridge type: 'wide' ridges. These have a much more regular, repeatable shape and are shown by the green boxes on the images above.

From these images, we are then able to map the surface in 3D using the laser confocal microscope. Here we show a wide ridge and the associated width and height of the ridges. Through other measurement tools (such as image analysis in Photoshop), we were able to verify this data with similar results.





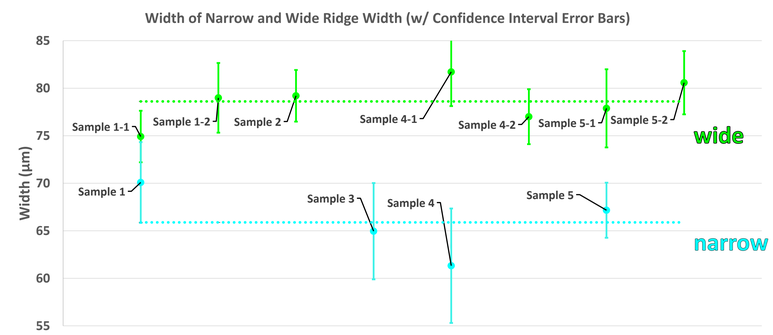
Sample	Wide Ridge Width (µm)	Std. Dev.	n	Conf.
Sample 1-1	74.9	8.5	38	2.7
Sample 1-2	79.0	11.2	36	3.7
Sample 2	79.2	7.6	30	2.7
Sample 3	Not present on this sample	---	-	---
Sample 4-1	81.7	10.4	32	3.6
Sample 4-2	77.0	9.6	42	2.9
Sample 5-1	77.9	9.1	19	4.1
Sample 5-2	80.6	12.0	50	3.3
Average	78.6	9.8		

Note: narrow ridges have a morphology that makes it impossible to find height values.

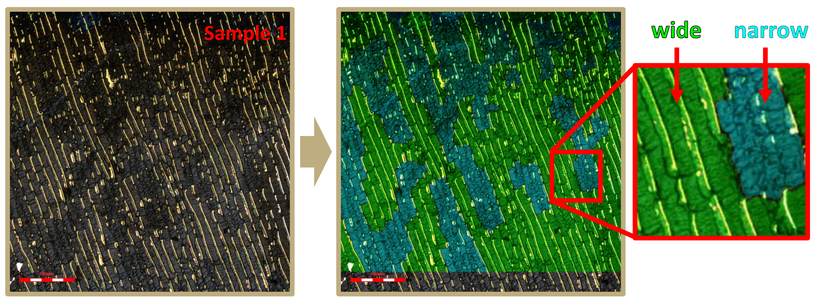
Sample	Narrow Ridge Width (µm)	Std. Dev.	n	Conf.
Sample 1	70.1	6.1	8	4.2
Sample 3	65.0	7.3	8	5.1
Sample 4	61.3	8.7	8	6.0
Sample 5	67.2	7.2	24	2.9
Average	65.9	7.3		

Sample	Wide Ridge Height (µm)	Std. Dev.	n	Conf.
Sample 1	0.800	0.142	24	0.057
Sample 2	0.887	0.145	49	0.041
Sample 3	---	---	-	---
Sample 4	1.024	0.169	12	0.096
Sample 5	0.711	0.132	23	0.054
Average	0.856	0.147		

Using the above method we have been able to produce data sets for both narrow and wide ridge widths with a high degree of accuracy. The narrow ridges average out to 65.9 microns across, while the wide ones average out to 78.6 microns. This is shown in a graph above as well.



From this graph, we can easily see the bimodal distribution between narrow and wide ridge width. We have also characterized how much of a sample the narrow and the wide ridges cover. For this, we once again use confocal images and then do a threshold in Photoshop to determine what percent of the image is covered (as seen below).



Although this is still a work in progress, we are still able to note some trends on the coverage of each ridge pattern. Samples 1 and 4 both show wide ridge coverages around 60%, but Sample 3 shows a huge difference in the pattern by being covered in only narrow ridges.

Sample	% Wide Ridge Coverage	% Narrow Ridge Coverage
Sample 1-1	59.95%	40.05%
Sample 1-2	60.93%	39.07%
Sample 3	0.00%	100.00%
Sample 4-1	58.94%	41.06%
Sample 4-2	65.48%	34.52%
Sample 4-3	63.13%	36.871%

Conclusion

- ❖ YBCO composite tape typically delaminates within the superconductor layer in a bimodal fashion (narrow and wide)
- ❖ Among samples that delaminated within the REBCO layer, a higher peel strength is correlated with a higher wide ridge coverage percent

Future work:

- ❖ Analyze more samples to verify our results and lower our confidence intervals
- ❖ Use this data to form relations linking breakage morphology to sample strength

Cryogenic Engineering Conference and International Cryogenic Materials Conference (CEC-ICMC) July 9-13, 2017

The authors thank the UWEC Office of Research and Sponsored Programs for student support at CEC-ICMC 2017.