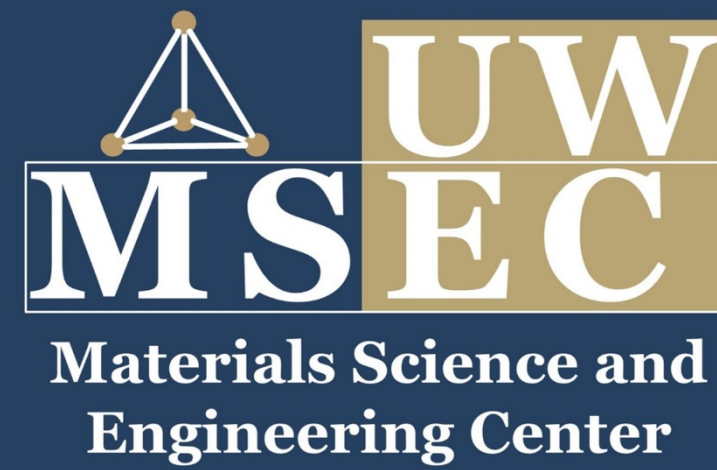


Characterization of REBCO Superconducting Tape Damage Induced by Various Sample Preparation Methods



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Introduction

What are we studying?

- ❖ Superconductors are materials that carry electric current with no resistance at cryogenic temperatures. When electric current flows through a superconducting coil it creates a strong magnetic field.
- ❖ Superconductors are used in, magnetic resonance imaging, particle accelerators, maglev trains and fusion reactors

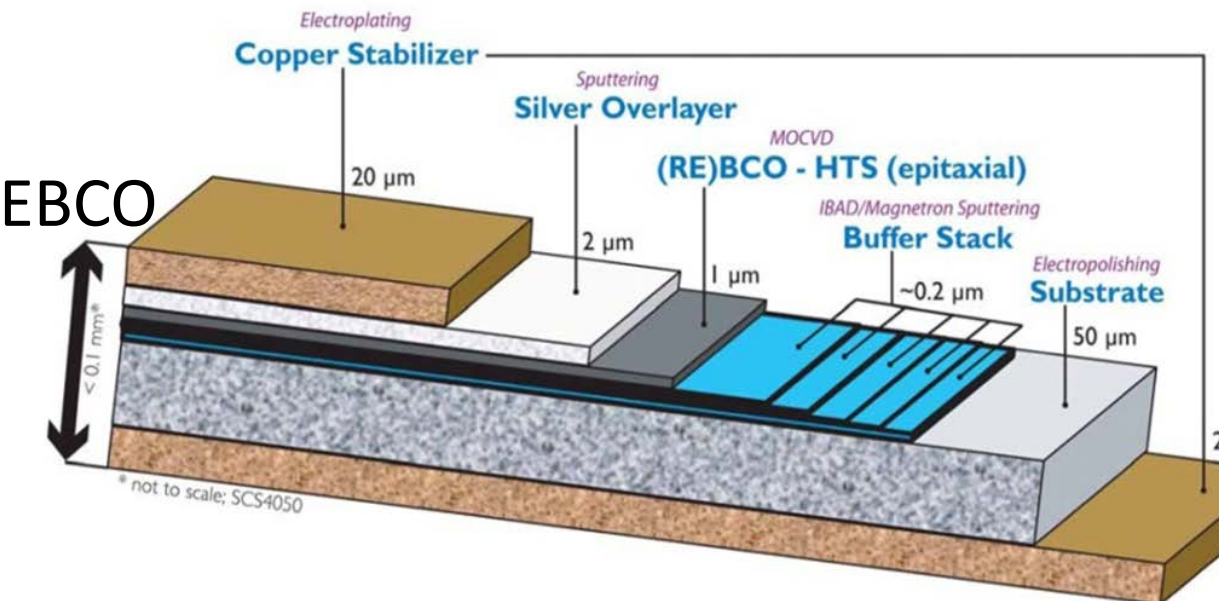
Why are we studying this?

- ❖ Manufacturing REBCO superconductors with uniform mechanical and electrical properties is challenging.
- ❖ Characterizing damage induced on REBCO superconducting tape is a step towards further understanding and improving the manufacturing process.



REBCO Tape

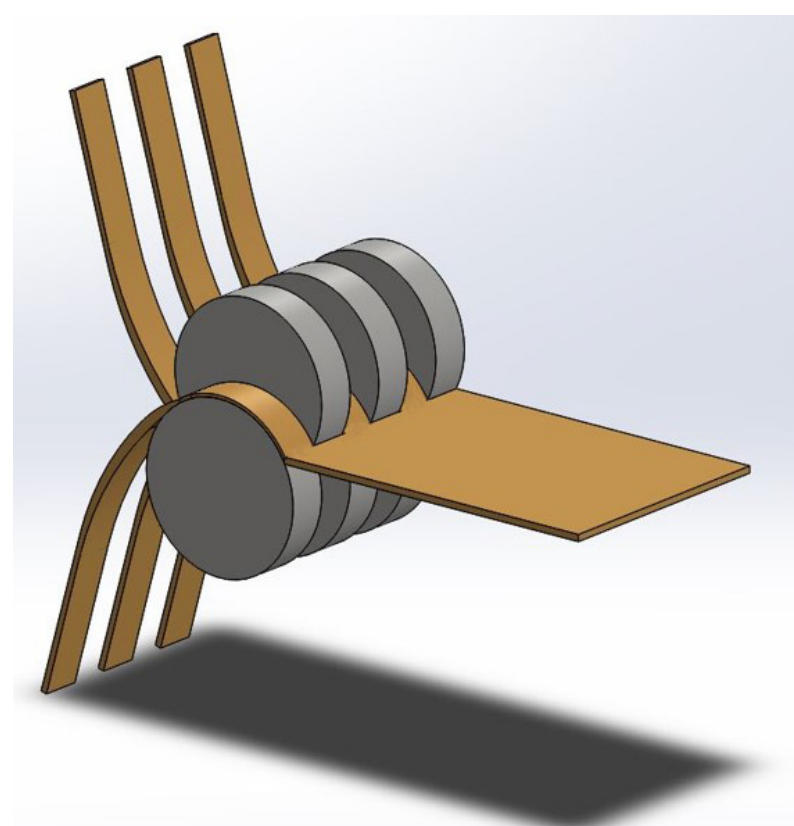
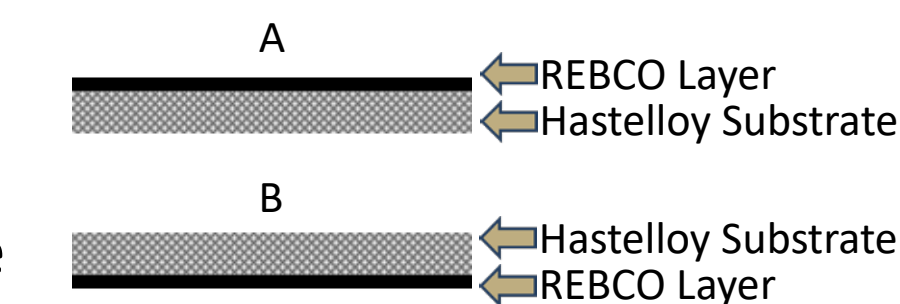
- ❖ Rare-earth barium-copper-oxide (REBCO) superconductors are high-temperature superconducting wires fabricated in a tape geometry.
- ❖ A REBCO tape has several layers consisting of:
 - Copper and silver layers for mechanical protection and electrical stability
 - REBCO superconducting layer
 - A collection of oxide buffer stacks that orient the crystal growth of the REBCO
 - A nickel-based layer (Hastelloy) for mechanical strength.



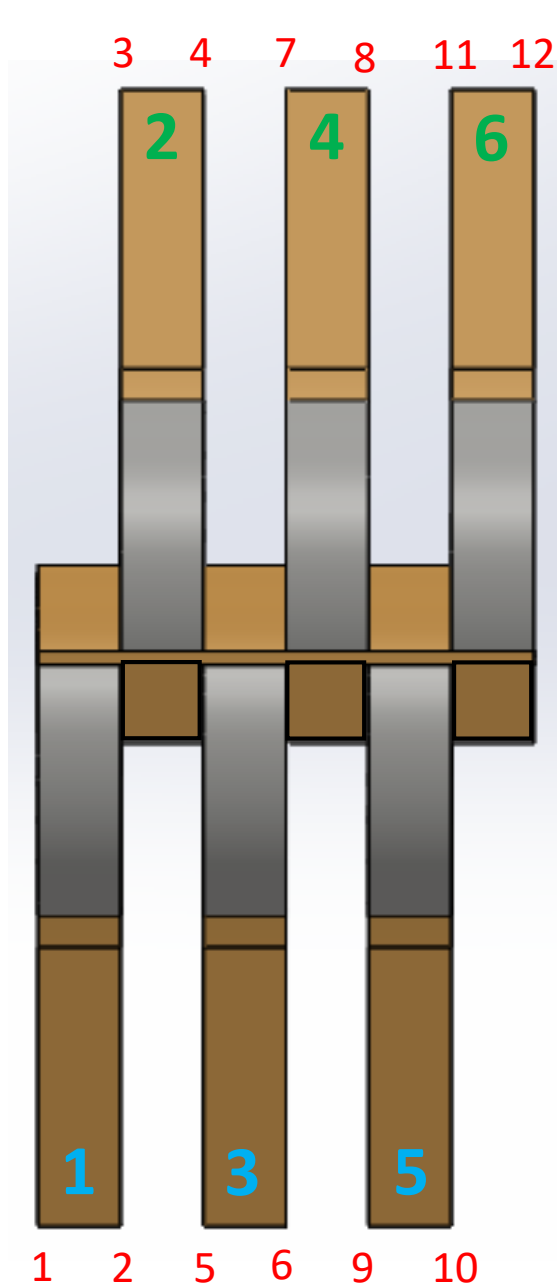
Cutting Procedure

Slit Edge

- ❖ The industrial slitting process consists of two sample sets being cut from a 12 mm wide tape, named as Sample A ("UP") where the REBCO layer is face-up during slitting process, and Sample B ("DOWN") where the REBCO layer is face-down during the slitting.
- ❖ Each sample is slit into 6 pieces (labeled as sample numbers 1-6) of 2 mm wide tapes with the slitter shown.
- ❖ The slitter has 6 knives, where each edge of a knife is given a code as "01, ..., "12."



Industrial Slitting process



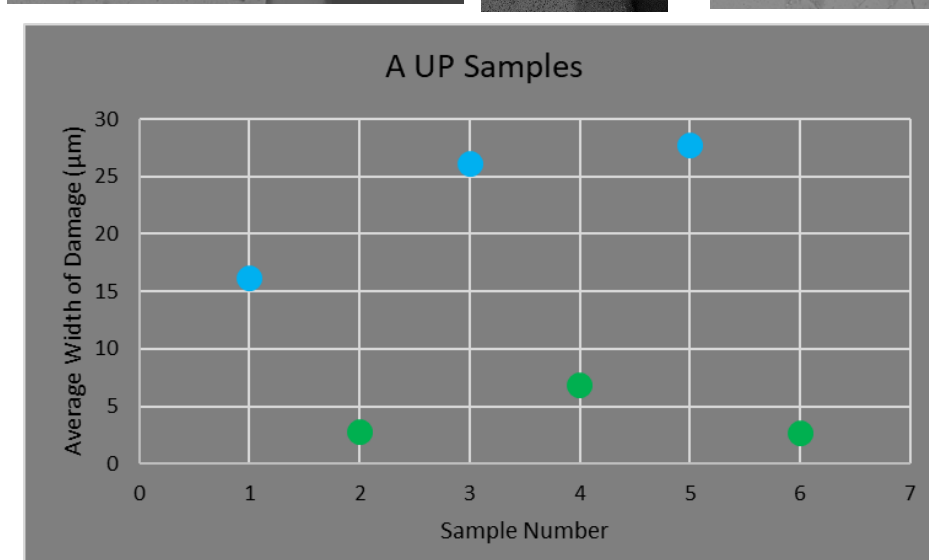
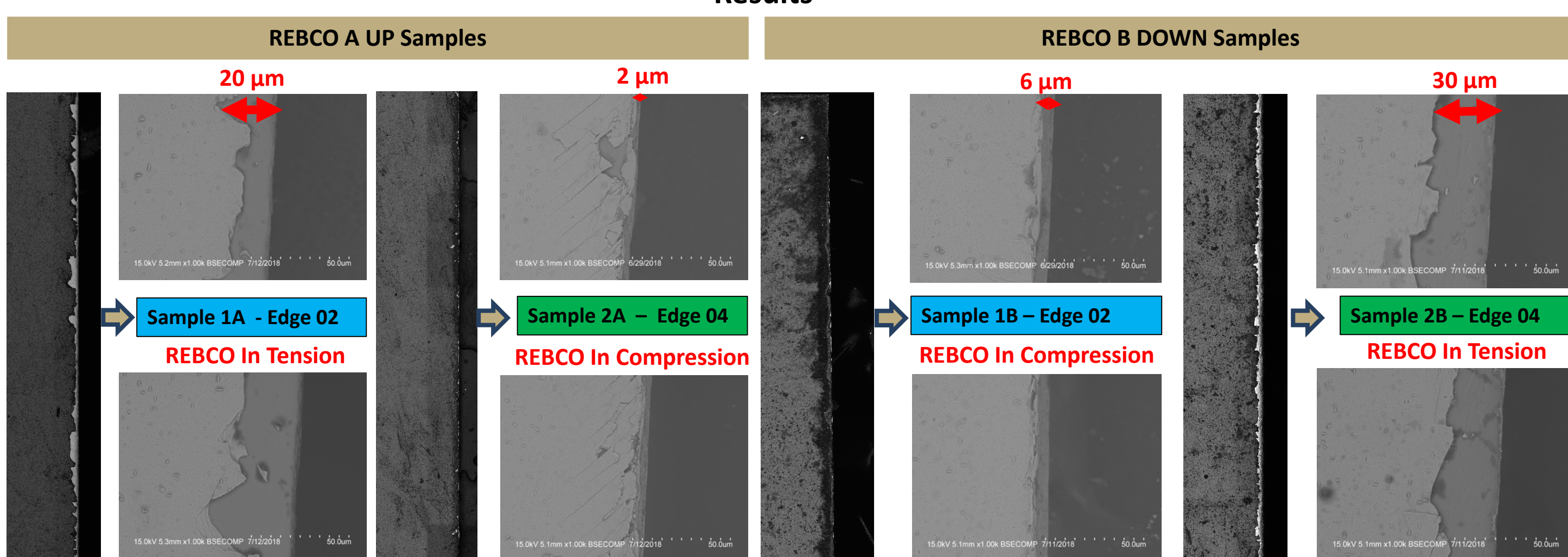
Schematic Explanation

- ❖ The Large Blue and Green numbers correspond to the sample number (1 – 6) of the slit piece.
- ❖ The small red numbers correspond to the edge number of the sample
- ❖ The schematic here is showing the relative positioning of the tape segments after they have passed through the slitting tool.

Procedure

- ❖ We investigated damage found on the REBCO/buffer layers by imaging the samples using laser confocal microscopy and Scanning Electron Microscopy (SEM). With this, we were able to analyze the fractures exhibited along the slit edge of the samples.

Results



Analysis

- ❖ The even numbered REBCO UP samples showed less damage along the slit edge, whereas the odd numbered samples exhibited a greater severity of damage (larger area of REBCO layer missing and larger area of buffer stacks exposed). The odd REBCO DOWN Samples showed less damage along the slit edge, whereas the even numbered samples exhibited a greater severity of damage. This trend in damage relates to whether the REBCO is in tension or compression. When the REBCO is under compression the damage is minimal. When the REBCO is under tension the damage is greater.

Summary

- ❖ Compression of the REBCO Layer during the slitting process leads to minimized damage
- ❖ Tension in the REBCO layer during the slitting process leads to increased damage

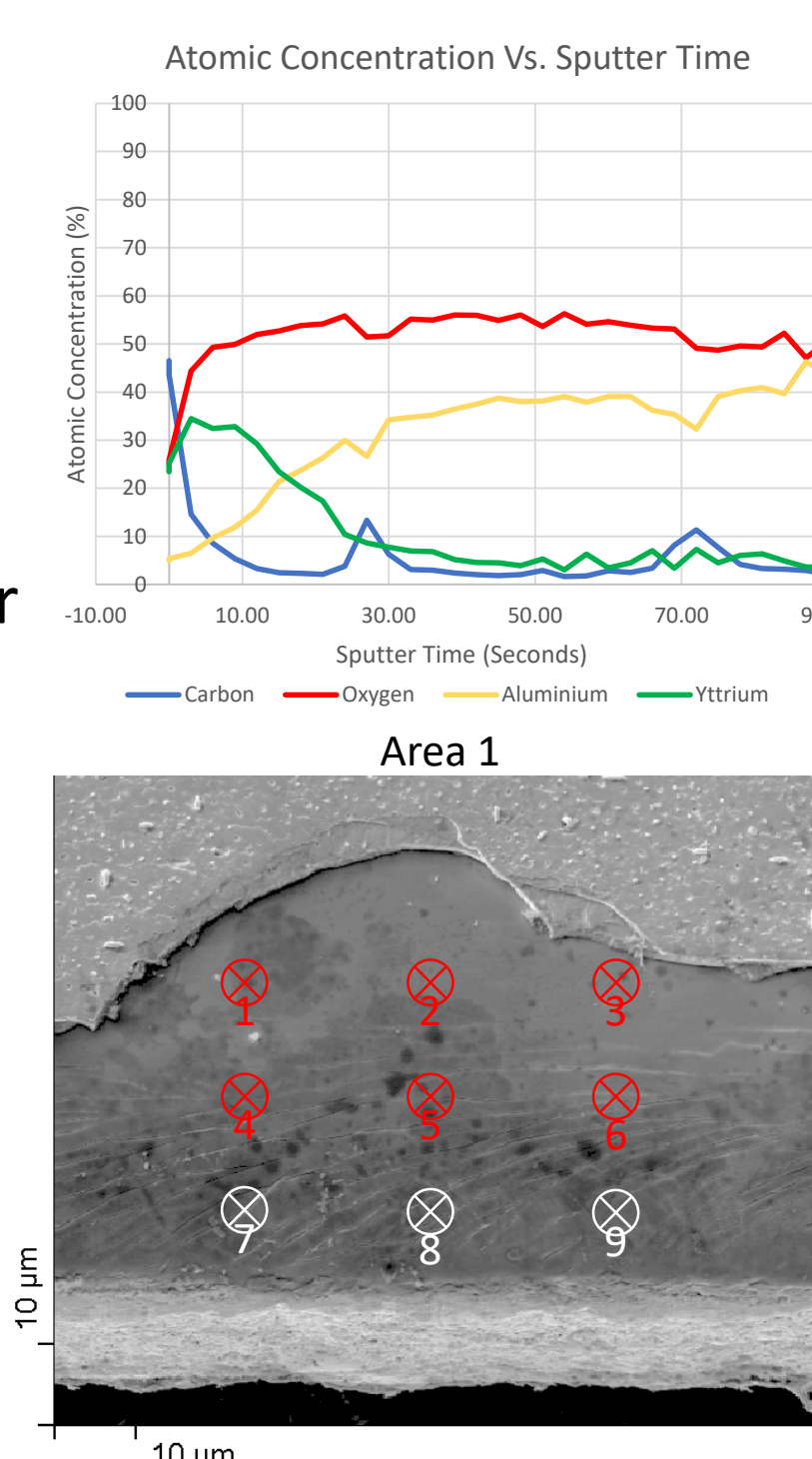
Chemical Analysis

Motivation

- ❖ Industrial slitting of REBCO superconductors causes fracturing in the REBCO layer which exposes part of the buffer layers. We hypothesize that the exposed buffer layer is the origin for mechanical failure and thus the weakest layer. The thickness of the exposed layer was needed in order to determine whether fracturing occurred at an interface or in the middle of a layer.

Procedure

- ❖ Using Auger electron spectroscopy and incremental Argon sputtering we were able to plot elemental composition as a function of sputtering time. If we have a sample where we know the thickness of a buffer layer, we can see how long it takes to sputter that layer and then calculate a sputter rate for that specific material.
- ❖ With the sputter rate, we can calculate the thickness of buffer layer by multiplying the sputter rate by the total time it took to sputter through the buffer layer.
- ❖ This procedure was used on one REBCO UP Sample and one REBCO DOWN.
- ❖ On each sample data was collected on three different locations.
- ❖ At each location data was collected at 9 points.
- ❖ Points marked in red were chosen for data analysis.



Results

- ❖ Error bars for the graph were calculated using a 95% confidence interval
- ❖ In both samples, the exposed buffer layer was identified to be yttria.
- ❖ The samples did not show significant differences in the average thickness of the yttria layer.
- ❖ Variance in the thickness of the yttria suggests that the fracturing occurred in the middle of the yttria layer.

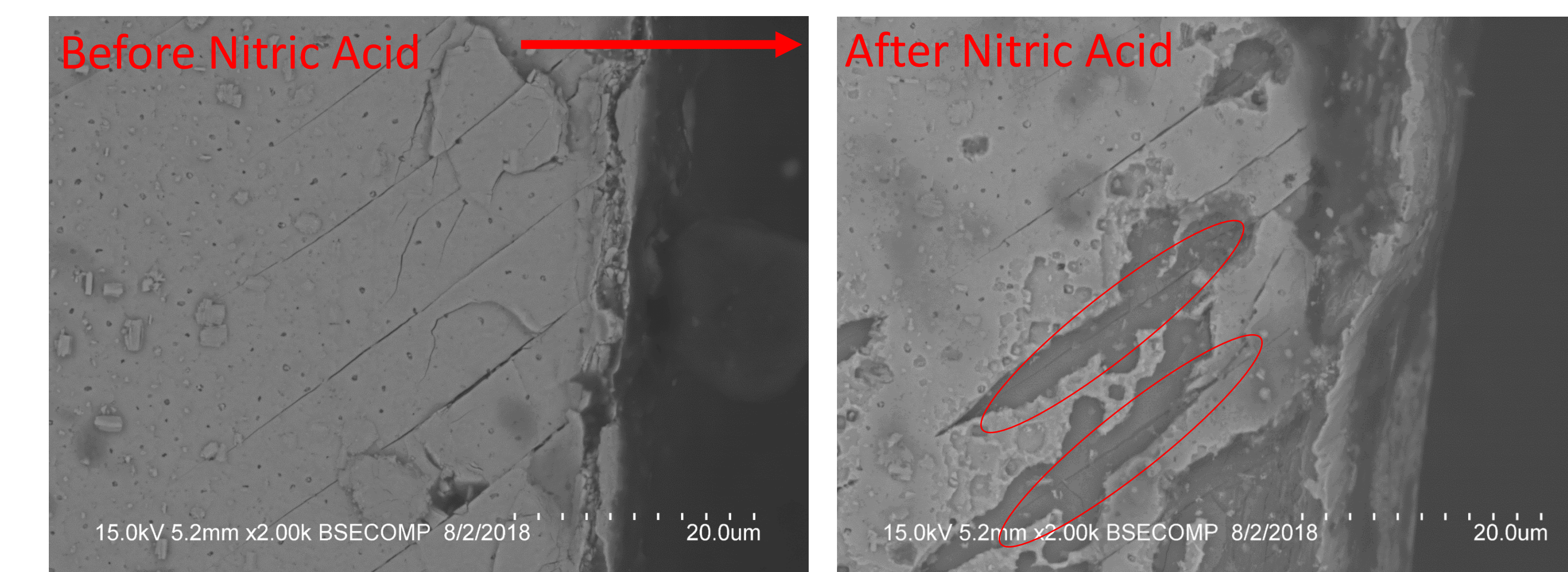
Summary

- ❖ The exposed buffer layer was identified as yttria on all areas of both samples
- ❖ Due to the measured thickness of the yttria layer it can be inferred that the fracturing occurred in the middle of the yttria layer. Further tests will be conducted to confirm this.

Crack Depth In Slit Edge Samples

Motivation

- ❖ For the industrially slit samples we wanted to see if the cracks in the buffer layers extended beneath the REBCO layer to the buffer stack, and whether the cracks in the buffer layers matched the cracks in the REBCO layer. To do this we used nitric acid to etch away the REBCO. We submerged the samples in increments of 5 seconds, imaging them in between each submergence.



Summary

- ❖ The cracks in the REBCO layer sit directly on top of similar cracks in the buffer stack.
- ❖ There is a clear propagation of the crack from one layer to the next. As the REBCO layer is thicker, we hypothesize that this layer cracks first, but we do not yet have evidence to support this.

Conclusions

- ❖ The damage in the REBCO layer under industrially slitting is more extensive when the REBCO experiences tensile stresses during cutting.
- ❖ Fracturing in the REBCO and buffer layers occurs in the middle of the Yttria layer.

Acknowledgements

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