Use of SEM/FIB and Machine Learning to Characterize REBCO Conductors

Hannah Matos-Pimentel, Carina Zha, Nicole Bishop, Keyou Mao, Jozef Kvitkovic, Jun Lu, Jeremy Levitan, Dmytro Abraimov

Microscopy and Microanalysis, **30** (Suppl 1), 2024, 466–467
https://doi.org/10.1093/mam/ozae044.217

Microscopy AND Microanalysis

Meeting-report

Use of SEM/FIB and Machine Learning to Characterize REBCO Conductors

Hannah Matos-Pimentel[1,*], Carina Zha[2], Nicole Bishop[2], Keyou Mao[3], Jozef Kvitkovic[2], Jun Lu[1], Jeremy Levitan[1], and Dmytro Abraimov[2]

[1]*National High Magnetic Field Laboratory, Florida State University, Tallahassee, FL, USA*
[2]*Applied Superconductivity Center, Florida State University, Tallahassee, FL, USA*
[3]*College of Engineering, Florida A&M University - Florida State University, Tallahassee, FL, USA*

*Corresponding author: hpimentel@magnet.fsu.edu

REBCO conductor, composed of rare earth elements (RE), barium (Ba), copper (Cu), and oxygen (O), stands out as a leading candidate among high-temperature superconductors (HTS) for the development of next-generation high-field magnets. Its exceptional ability to carry high currents in magnetic fields, along with its mechanical resilience, positions it as a promising solution for advanced magnet applications. The REBCO conductors exhibit superconductivity at significantly higher temperatures than conventional low-temperature superconductors [1-3]. In this present study, we characterize and explore the microscale defects layer thickness on a commercial REBCO-coated conductor and correlate it with the in-field transport critical current (I_c) at a fixed orientation and critical current density (J_c) calculated using the equation:

$$J_c = I_c/A \tag{1}$$

We acquired top-view images from the REBCO layer after etching the coaters at different areas using the Scanning Electron Microscope with Focused Ion Beam (SEM/FIB) Thermo Fisher Helios G4 UC. We used the FIB to expose the cross-sections and measure the REBCO layer thickness (Fig. 1). Additionally, for quantitative analysis of the large-scale structural non-uniformities, we used the machine learning software Trainable Weka Segmentation in ImageJ [4].

The defects were categorized, then correlated with REBCO layer thickness and Jc using the transport properties, when Ic at 4.2 K, 14 T in field 90° (Fig. 2). Although there is no visible correlation between the type of defect or thickness in the variation of Jc, it was observed a Jc fluctuation within the same REBCO thickness layer interval. When evaluating the variation of Jc as a function of the percentage of precipitates, we noticed that the increase in the non-uniformities and precipitate percentage decreases the Jc, as exemplified in Figure 2 from A to F. This result provides further evidence that the microscale defect type, such as copper oxide grains, a-axis grains, and porosity, can affect the current measured in REBCO tapes [5].

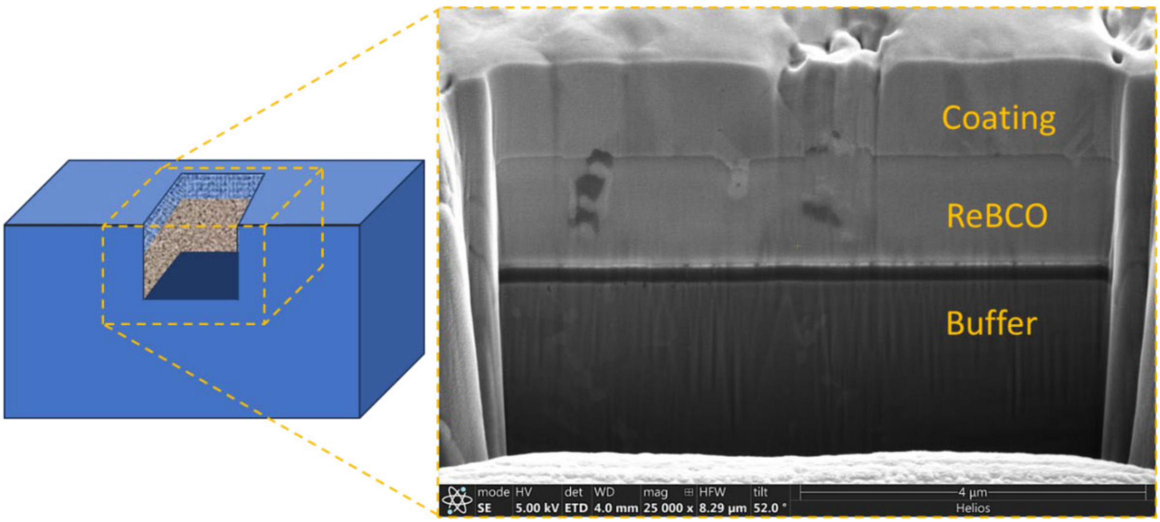

Fig. 1. Illustration showing a cut region using FIB (left) and cross-sectional view exposing the layers composed of coating (silver or copper), REBCO, and buffer (right).

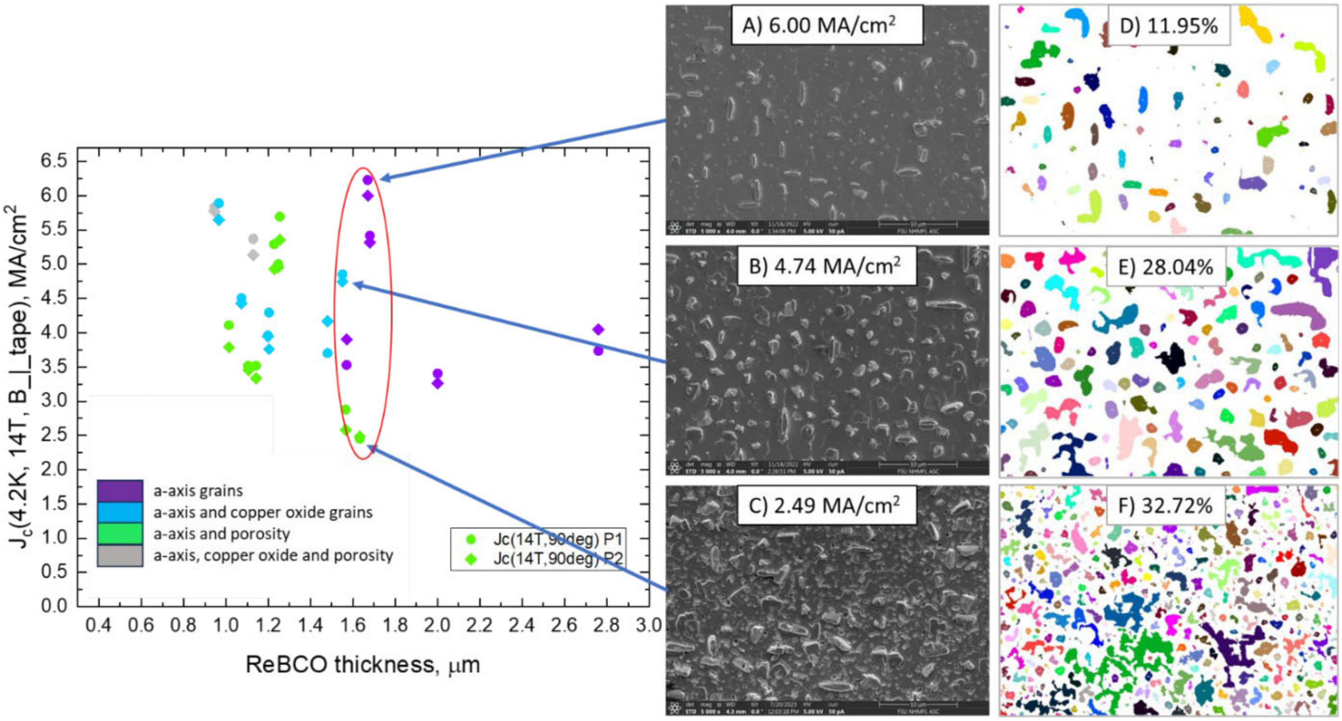

Fig. 2. The graph on the left correlates the thickness of the REBCO films and the critical current density (Jc). The thickness range between 1.5 and 1.7 is highlighted (red marker) and is correlated with the quantitative percentage of defects in the top view images of the REBCO tapes (A to C), showing the variation of Jc (D to F).

References

1. JL MacManus-Driscoll and S.C. Wimbush, *Nature Reviews Materials* **6** (2021), p. 587. https://doi.org/10.1038/s41578-021-00290-3
2. S Hahn *et al.*, *Superconductor Science and Technology* **29** (2016), p. 105017. https://doi.org/10.1088/0953-2048/29/10/105017
3. X Hu *et al.*, *IEEE Transactions on Applied Superconductivity* **27** (2017), p. 1. https://doi.org/10.1109/TASC.2016.2637330
4. I Arganda-Carreras *et al.*, *Bioinformatics* **33** (2017) p. 2424. https://doi.org/10.1093/bioinformatics/btx180

5. This work was performed at the National High Magnetic Field Laboratory, which is supported by National Science Foundation Cooperative Agreement No. DMR-1644779, DMR-1938789, DMR-2131790 and the State of Florida.