Stability and Normal Zone Propagation in YBCO Coated Conductors

Robert C. Duckworth and John M. Pfotenhauer
Applied Superconductivity Center, University of Wisconsin-Madison

Michael J. Gouge and J. Winston Lue
Fusion Energy Division, Oak Ridge National Laboratories

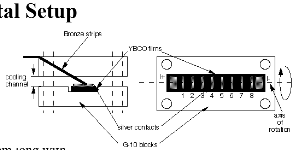
Abstract

We report on normal zone propagation measurements in $YBa_2Cu_3O_x$ (YBCO) coated conductors. The measurements describe the behavior of conductors fabricated with the Rolling Assisted BiAxilally Textured Substrates (RABiTs) technique when transport current pulses were applied. The pulse magnitudes varied between 9 A and 70 A and pulse durations ranged between 0.5 s and 5.0 s. Comparing the magnitude of the pulse to the local critical currents, I/I_c was between 1.25 and 35. Furthermore, the results compare the influence of bath cooling in liquid nitrogen to conduction cooling with a cryocooler. The nominal sample dimensions examined were 1 cm in width, a YBCO thickness of 0.5 µm, and 5.0 cm in length. The corresponding current densities ranged from 1 to 2 MA/cm^2. The normal zone propagation measurements were provided by voltage taps equally distributed along the conductor length. Normal zones that were generated by over-current pulses in liquid nitrogen recovered to the superconducting state, while those samples that were cryocooled showed a potential for damage near the region of lowest, local critical current.

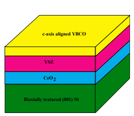
I. Introduction

- Motivation
  - Previous HTS materials (Bi-2212 and Bi-2223) suggest a possible dependence of normal zone propagation on geometry of stabilizing material to superconductor and cooling conditions (i.e. conduction vs. convection).
  - Range of knowledge on YBCO currently limited in this regard.
  - With improvements in YBCO, knowledge of normal zone propagation will prove essential to successful application to areas like wires, current limiters, and magnets.
- Objective
  - To classify the formation of normal zones in Rolling Assisted BiAxially Textured Substrate (RABiTS) YBCO films with respect to the following
    - Electrical disturbances with DC pulsed power supply providing currents up to 70 A for durations between 1 s and 5 s.
    - Conduction/convection cooling conditions

II. Experimental Setup



- Sample material
  - RABiTs YBCO
- Sample dimensions
  - 1 cm wide by 5 cm long with nominal thickness of 0.5 µm.
- Cooling conditions
  - Liquid nitrogen bath cooled (77 K) with the cooling channel oriented in the horizontal and vertical directions.
  - GM cryocooler (20 K)

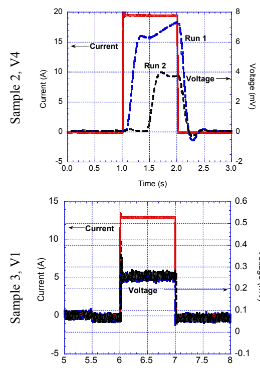


III. Results and Analysis *(LN_2 Results)*

Critical currents of samples at 77 K

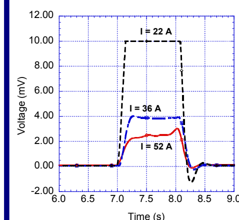
Voltage Region	Sample 1 I_c [A]	Sample 2 I_c [A]	Sample 3 I_c [A]
V1	2.17	9.66	9.37
V2	1.38	11.16	7.99
V3	4.04	8.00	7.73
V4	3.39	7.40	8.43
V5	5.50	8.60	8.81
V6	5.44	8.40	10.51
V7	3.86	11.11	11.23

Repeatability of voltage response for similar current disturbances

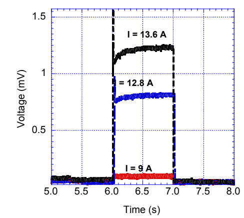


Some samples, like sample 2, demonstrated inconsistency in the voltage response when the same current pulse magnitude is applied

Comparison of voltage response to increasing current pulses of 1 second in duration



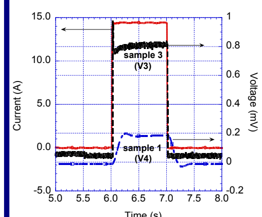
Sample 1, region V6

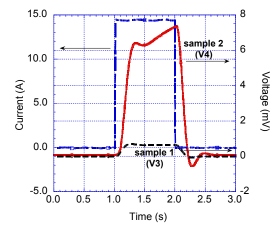


Sample 3, region V3

The voltage response in sample 2 **decreased** with increasing current instead of **increasing** with increasing as shown in sample 3

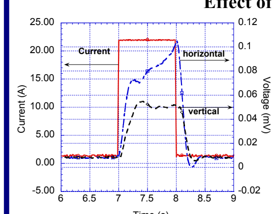
Comparison of normal zone voltages of sample in areas of different local critical currents



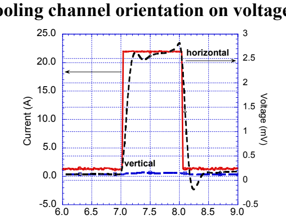


Regions of higher critical current had a **greater** response than areas of lower critical current to equivalent current pulses.

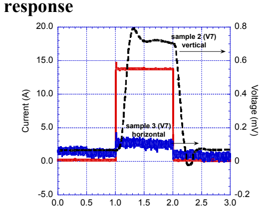
Effect of cooling channel orientation on voltage response



Sample 2, region V1



Sample 2, region V3



While voltage response in sample 2 showed an increased voltage response for the horizontal orientation when compared to the vertical orientation, similar region of critical current from samples 2 and 3 showed the opposite.

III. Results and Analysis

b. Cryocooled Results

- Sample 2 (shown above) did not survive at 14 A, 1s pulse at a temperature of 20 K. Sample 2 was thermally anchored to the G-10 piece.
- Sample 3 did survive currents up to 14 A after the G-10 base was replaced with copper. However, failure of current leads prevented identification of normal zones at higher currents.

IV. Conclusions

- LN_2 cooled samples are more stable to current disturbances than those that were conductively cooled.
- LN_2 tests
  - Decreasing voltage response with increasing current suggests that the current travels through the nickel substrate.
  - Sample regions with similar I_c display inconsistent voltage responses.
  - Cooling orientation affects the magnitude of the voltage response (not always as expected).
- Cryocooled tests
  - Thermal contact to sample plays a key role in stability.
  - Potential for damage is significant when normal zone appears in area without sufficient cooling and lowest I_c.

V. Future Work

- Take additional measurements at high currents for both RABiTs and non-metallic substrate YBCO to clarify role of nickel.
- Investigate role of individual sample processing and cooling conditions, both conduction and convection.
- Study the influence of a complete layer of Ag on YBCO on normal zone propagation with respect to defects which cause dissapation at the Ag/YBCO interface.
- Measure contact resistance of Ag/YBCO interface and compare to normal zone propagation.
- Additional samples generated by similar processing parameters are required to better determine the influence of cooling conditions and current pulses.