Visualization of dissipation at different magnetic field orientations in RABiTS coated conductors

Dmytro Abraimov, Pei Li, David Larbalestier
Applied Superconductivity Center, National High Magnetic Field Laboratory, 242 Shaw Building
2031 East Paul Dirac Drive, Tallahassee, FL 32310
Xiaoping Li, Marty Rupich
American Superconductor Corporation, 64 Jackson Road, Devens MA 01434 USA
Marcus Weigand, John Durrell, Noel Rutter
Department of Materials Science and Metallurgy, University of Cambridge, United Kingdom

1. Motivation;
2. Technique;
3. Voltage response maps at different orientations measured on TFA-MOD YBCO on RABiTS;
4. Conclusions
• Application of YBa2Cu3O7-d coated conductor (CC) in magnets and generators becomes much more promising due to the recent progress in engineering pinning centers, which allow better in-field YBCO properties.

Since magnetic field orientation and value strongly affects $J_c$ visualization of the local electric field for different external magnetic field orientations becomes important.
Motivation 2: Magnetic field distribution in a coil

Example Coil:
Diameter 20 mm
Wire diameter 0.5 mm
Number of turns 200
Coil length 10 cm

Motivation 2: Magnetic field distribution in a coil

0
X
B
α
Z

\[ B_x/B_{\text{max}} \]

\[ B_z/B_{\text{max}} \]

Winding number

\[ \alpha, \text{deg.} \]

\[ \mathrm{Color \ scale:} \ B/B_{\text{max}} \]

\[ \mathrm{Number \ of \ turns} \]

\[ l\alpha l < 5^\circ \]

for \( \approx 70\% \) conductor
Critical current dependence on magnetic field angle

YBCO GB and in-grain (bicroystal)

TFA-MOD YBCO on RABiTS link (polycrystal)

FIG. 1. Critical current dependence on magnetic field angle, $\phi$, for an in-grain (IG) track and a grain boundary crossing track (GB). The inset defines the field rotation angle, $\phi$, and indicates the direction of the Lorentz force, $F_L$, on the flux lines. The angle at which the behavior of the GB track deviates from the in-grain behavior is defined as $\phi_k$.


Data from Marcus Weigand, John Durrell, Noel Rutter
**Technique:** Low Temperature Scanning Laser Microscope

- Detecting intensity of reflected light allows to see photo image of the sample.
- Thermo-power response allows to see grains boundaries and other defects which affect transport properties.
- Low temperature response shows local electric field map.

Sample holder with mirror for B parallel to sample plane measurements.
Visualization with different magnetic field orientations

With LTLSM we see vortex channels.

$B_{llc}$

Vortices are penetrating easier into cross sections with reduced $J_c$.

$B_{llab}$

Vortices move through film thickness. For rigid vortices, there is no $F_{Lorentz}$ that pushes the vortices in the a-b plane.

Vortices move perpendicular to a-b plane. $J$ percolates around defects, which changes the direction of $F_{Lorentz}$. 

$F_{Lorentz}$
GB misorientation map

GBs are lesser obstacles when B is parallel to the tape plane and the Lorentz force is non zero.
Since GBs are irregular therefore no considerable drop in $I_c$ for matching field orientation.
Force free configuration correlates with GB network

\[ I_b = 0, \quad I_{bias} = 752 \text{ mA} \]

\[ B \]

1.0 T, \( I_{bias} = 480 \text{ mA} \)

\[ dV \propto E \]

5.0 T, \( \alpha = 0^\circ, \quad I_{bias} = 752 \text{ mA} \)

GB misorientation map

\[ T = 78 \text{ K} \]

Obstacles appear again in the nominal force-free geometry.
Dissipation varies with I-B configuration

\[ dV \propto E \]

Full Lorentz force

- 0.46T
- 1T
- 1.45T
- 5T

Variable Lorentz force

- 5T 90°
- 5T 75°
- 5T 55°

Nominal force free

- 5T 0°

- 0.04 μV
- 1.547 μV

\[ T=78 \text{ K} \]

50 μm
Local electric field is increased in cross-sections with defects.

Thermo-power response shows grains

Photo image

TFA-MOD YBCO on RABiTS link patterned and measured by Marcus Weigand, John Durrell, Noel Rutter
Nominal Lorentz force free regime.

Where LTLSM voltage signal can appear?

To move vortex FL ≠ 0
\[ \mathbf{J} \times \mathbf{B} \neq 0 \]

A-axis grains, highly misoriented, low \( J_c \) grains.
$\langle V \rangle \approx 58 \ \mu V$

83.6 K

Response from strong blockage is dominating in all fields and orientations

Thermo-power response
Voltage signal increases at 45° between the B and $I_{bias}$ when the magnetic field matches the row of a-axis grains.

Nominal force-free dV map is similar to B II c dV distribution.

Thermo-power response

$\langle V \rangle \approx 58 \mu V$

83.6 K

$V_{amplitude\ rescaled}$
Conclusions

- For BIIab orientation the electric field is more homogeneous and appears as lines that follow the external magnetic field;
- Larger electric field detected if the magnetic field matches orientation of GB or cross-section with high density a-axis grains;
- Therefore for CC with low angle GB network hot spots may develop in different areas for different field orientations;
- In nominal “Lorentz force free regime” the dissipation is highly sensitive to defects

Planning LTLSM visualizations in other magnetic field orientations:

![Diagram showing B and α relationships](image)