Electrical and mechanical properties of exfoliated YBCO filaments

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Outline

• Why do we need new conductor geometries
• BTG cable geometry and its advantages
• Exfoliated filament test results:
  • Electrical tests
  • Mechanical tests
• Conclusion and future work
Brookhaven Technology Group

• Founded in 1987
• Located in Stony Brook, NY
• First HTS project: ARMY SMES system
• Currently two Phase I SBIR on HTS applications
Why do we need new 2G cable geometries

- High AC loss, complicated joints, poor quench stability are intrinsic to 2G
BTG exfoliated filament process

2G tape

- Stabilizer
- Silver
- YBCO
- Buffer
- Substrate

Exfoliation

- Buffer
- Substrate

Protective silver

- Silver

Laser slicing

- Laser cut

Copper/solder plating

- Twisted filament stack
- Sheath

Cabling

- Multi-strand cable
Advantages of the exfoliation

• Narrow filament, low AC loss: we are cutting though less layers

• Electrical coupling between filaments:
  • Simplified joining of multi-strand cables
  • Current sharing during a quench

• Low mass of the winding

• Substrate does not compromise mechanical properties

• For FCL and cable applications:
  • High “off” resistance at the same protection level
  • No magnetic substrate, reduced magnetization loss
Electron microscopy analysis of the exfoliated YBCO surface

SEM: plane view

SEM: edge view

✓ The YBCO surface roughness is below 100 nm
Slicing of the tape by a commercial CO$_2$ laser

250 W CO$_2$ laser, 10”/second cut

Laser cut cut

✓ Laser slicing does not degrade $I_c$ in narrow filaments

Weak width dependence of $I_c$
Critical current of the filaments

High n-value

Retention of $I_c$

Independent validation at AMSC facility

✓ Both $I_c$ and n-value of the YBCO layer are retained
4.2 K in-field test of the 1 mm wide filament

✓ 4.2 K $I_c$ is consistent with the 77 K data

Original $I_c$ value at self-field

$\alpha = 0.8$
Tensile strength test of the filament

✓ The superconducting layer failed at 560 Mpa.
Failure of the filaments

Strained filaments

Cross-wise micro-cracks develop at 560 Mpa.
Splice resistance, Ag-coated YBCO side

Cannot be annealed

✓ Both sides of the filament have splice resistance below 500-200 nΩ/cm²
Tests of 1 mm filament bundles

✓ Current transfer effects are noticeable in a short sample
Bending and twisting tolerance

- Critical bending radius approximately 10 mm for a two-filaments wire
- For a single 2 mm filament critical twist pitch 50 mm
critical bending radius 7 mm
Bend an twist tolerance summary

✓ 15 mm bend radius, 50 mm twist pitch

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Future work: long-length cabling
Summary

• Retention of 90% of $I_c$ in short sample
• Multi-strand wire coupons show filament current sharing
• The exfoliated surface has low resistance
• Good bending (15 mm radius) and twisting tolerance
• Tensile strength 560 MPa
• Further work
  • Demonstration of long length cabling
  • Mechanical tests of the multi-strand cable
  • Demonstration of a test coil performance in external field

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