



TESTS OF HTS INSERT COILS ABOVE 30 T

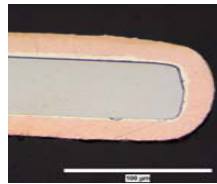
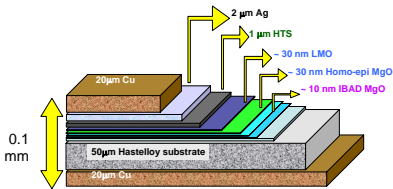
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Abstract

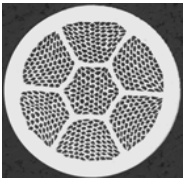
Recently HTS insert coils have been operated in background magnetic fields over 30 T, reaching record values for the central magnetic field. One YBCO double pancake coil generated 2.8 T in a 31 T background for a total of 33.8 T. A Bi-2212 layer wound coil generated 1.1 T in a 31 T background for a total of 32.1 T. Here we report on the test set-up and the obtained results.

Introduction

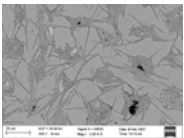
- Goal: demonstrate the suitability of HTS conductors > 30 T
- Two insert coils are built and tested in a background magnetic field of 31 T.
 - 1) YBCO insert coil with commercial conductor from SuperPower Inc.
 - 2) Bi-2212 coil using commercial ϕ 1 mm wire from Oxford Instruments, Superconducting Technology (OST).
- Coils are wound and tested at the NHMFL in a 31 T resistive magnet with a 39 mm diameter cryostat.
- HTS coils were protected with a quench detection system, circuit breakers and a 0.5 Ohm dump resistor



Sketch of YBCO conductor (left) and actual cross section (above)



Bi-2212 wire cross section before heat treatment.



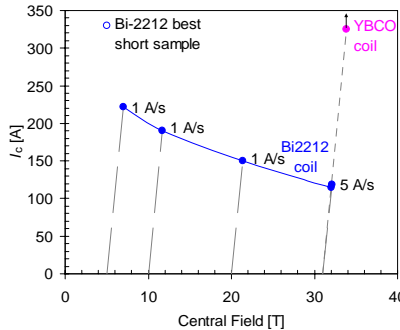
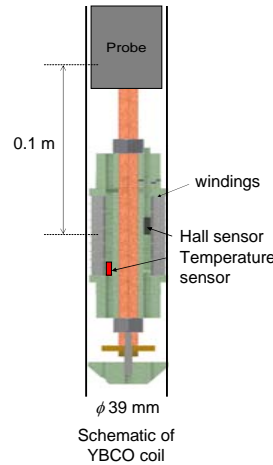
Detail of Bi2212 filaments after heat treatment



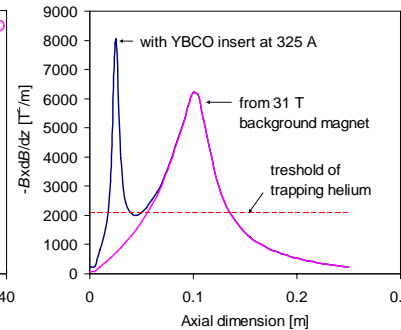
Picture of Bi-2212 coil after heat treatment



Picture of YBCO coil on winder



Measured critical current of the Bi-2212 coil and quench current of the YBCO coil



Downward magnetic force of helium gas bubbles compared to buoyancy

| | units | YBCO coil | Bi-2212 coil |
|------------------|-------------------|------------------------|----------------------|
| Conductor | | 4 by 0.1 mm tape | ϕ 1 mm wire |
| Typical I_c | A | 120 A at 77 K, SF | 330 A at 4.2 K, 5T |
| Insulation | | varnish | ceramic braid |
| ID-OD | mm | 25-36 | 15-37.5 |
| Winding height | mm | 46 | 100 |
| Windings | - | 5 double pancake units | 10 layers, No joints |
| Impregnation | | none | Epoxy VPI |
| # turns | - | 380 | 750 |
| Conductor length | m | 36 | 66 |
| Self-inductance | mH | 1.9 | 2.6 |
| Field constant | mT/A | 8.7 | 9.1 |
| I_c (31 T) | A | >325 | 120 |
| J_{ave} (31 T) | A/mm ² | >459 | 80 |
| J_{ave} (25 T) | A/mm ² | >459 | 92 |

Results

Bi-2212 coil

- The onset of a resistive transition could be measured up to a ~ 5 mV, ($\sim 0.1 \mu\text{V/cm}$) at which point the coil would quench.
- Repeated quenches did not degrade the coil performance.
- The shape of the $I_c(B)$ curve is similar to short samples.
- Coil I_c is $\sim 70\%$ of short sample I_c at 5T

YBCO coil

- Ohmic heating in the probe caused helium boil off. Magnetic forces (see left figure) traps the gas, resulting in a significant temperature rise while the coil is still superconducting.
- Coil is operating at estimated 60% of short sample I_c
- Coil degraded during run 5, before reaching $I_c(4.2K)$, cause probably mechanical

Discussion

Bi-2212 coil

- Conductor has preferred wire geometry
- Coil performance is large fraction of short sample wire performance
- Heat treatment not fully optimized. Increased conductor and coil performance possible with further conductor development and heat treatment optimization.
- Current density suitable for 25 T magnets. (J_{ave} near 100 A/mm² at 25 T)

YBCO coil

- Central field of **33.8 T** is a **world record for a superconducting coil**
- Magnetic properties of helium combined with Ohmic heating in the probe caused unstable temperatures and **limited coil performance**.
- Current density is suitable for > 30 T magnets
- Probe and coil design need to be integrated to reduce heating
- Coil mechanical structure needs improvement

Summary

- A Bi-2212 wire wound solenoid and a YBCO double pancake coil were built and reacted at the NHMFL and operated in a 31 T background magnetic field.
- The Bi2212 coil reached 32.1 T at an average winding current density of 80 A/mm²
- The YBCO coil reached 33.8 T at an average winding current density of 359 A/mm², which is a world record for HTS insert coils
- Both conductors are promising for HTS inserts

E.J. McNiff, B.Brandt, S.Foner, L.G. Rubin, R.J. Weggel, "Temperature anomalies observed in liquid ⁴He columns in magnetic fields with field-field-gradient products > 21 T²/cm," *Rev. Sci. Instrum.*, vol. 59, pp. 2474-2476, 1988.

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