Improved critical current density in recent Bi-2212 round wires


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Our external collaborators

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- Andrew Hunt, Marvis White, Aixia Xu and Riley Nesbit of nGimat.
- Suvankar Sengupta and Rao Revur of MetaMateria.
- Tengming Shen of LBNL.
- Alex Otto of Solid Materials Solutions (SMS).
- Other presentation at EUCAS:
  - T. Shen, 4LO2-04, Bi-2212 Racetrack coil (this afternoon).
Many architectures of Bi-2212 Round Wire

- A flexible conductor technology: PIT.
- Excellent conductivity matrix without any need for diffusion barrier.
- Twisted, multifilament, isotropic, low loss conductor with high RRR (> 100).
- The conductor technology is mature at present scale.
  - Single 10 kg piece lengths: 2.4 km at 0.8mm, ~1 km at 1 mm.
- Insulation technology for single wire is good.
- Concern about low E and low yield strength.
- Wind and React for coils

Made by Bruker-OST

Twisted longitudinal section

Rutherford cable with 17 strands
Good conductors start with good powder

- Composition (Nexans 521 to 524 series)
  - 521 (\(\text{Bi}_{2.17}\text{Sr}_{1.94}\text{Ca}_{0.90}\text{Cu}_{1.98}\text{O}_x\)) was the best.

- Particle size and distribution
  - Issue of hard particles in Nexans lots 80 and 82.
  - Nexans final powder: lot 87 (the benchmark).

- Tap density
- C and H content: lower than 50 ppm
- Low content of impurity phases, Bi-2201, alkaline earth cuprates (AEC)
Two companies now making Bi-2212 powder in US

- Nexans was sole source of Bi-2212 powder until 2015 when they quit making powder
- Two US companies now making powder
  - MetaMateria
    - Use chemical co-precipitation
  - nGimat
    - Use spray combustion to form 2212
- Reproducing Nexans 521 composition
- New 2212 powders are better than the best Nexans powder.
Nexans lot 87 was the benchmark for powder

Still some hard particles with reduced size, less impact on filament merging.

\[ J_C(4.2K, 5T) = 5600 \text{ A/mm}^2 \]
\[ J_E(4.2K, 5T) = 1100 \text{ A/mm}^2 \]
Earlier MetaMateria powders contain large localized Bi-2201 particles, and Al and Ni-Fe.

Bi-2201 particles (>20 µm)  Ni-Fe-O and Cu-free
Recent MetaMateria powder has few impurity phases

Powder MM-237

After powder densification

Some Bi-2201

1.2 mm, FF = 0.22
New MetaMateria powder is very similar to Nexans

After 50 bar OP-HT

\[ J_C(4.2K, 5T) = 5670 \text{ A/mm}^2 \]
\[ J_E(4.2K, 5T) = 1250 \text{ A/mm}^2 \]
Impurity phases in nGimat powder have decreased with time.

- nGimat LXB-43: Some Bi-2201 (white), AEC-14/24 (black), and Cu-free (next to 2201)
- nGimat LXB-52: No Cu-free and Bi-2201, with large AEC-14/24 particles
New record $J_C(4.2K, 5T)$ from nGimat powder
70% increase for $J_C(4.2K, 5T)$ over Nexans lot 87

$I_C(4.2K, 5T) = 914 \text{ A (0.78 mm diameter)}$
$J_E(4.2K, 5T) = 1900 \text{ A/mm}^2$
$J_C(4.2K, 5T) = 9530 \text{ A/mm}^2$
$J_E(4.2 \text{ K}, 15 \text{ T}) = 1365 \text{ A/mm}^2$ and $n$ of $\sim 30$

$I_C(4.2\text{K}, 15\text{T}) = 658 \text{ A (0.78 mm diameter)}$

$J_E(4.2\text{K}, 15\text{T}) = 1365 \text{ A/mm}^2$ (2x of FCC target)

$J_C(4.2\text{K}, 15\text{T}) = 6860 \text{ A/mm}^2$
the wire drawing is excellent for different diameters wire dia. from 1.5 to 1.0 mm (Nexans lot 87)

Densified 1.4 mm wire

Densified 1.0 mm wire

$J_C$ is independent of the initial filament size

Very similar filament size distribution

Transport $J_c$ (5T, 4.2K) does not systematically vary with twist pitch: twisting is not damaging the wires, even for tight twists of 12 mm

Y. Oz et al., ICMC-2017
Twisting reduced losses by ~25% for 37x18 and ~70% for 27x7

Y. Oz et al., ICMC-2017
• nGimat and MetaMateria are new Bi-2212 powder sources.

• New record $J_E$ and $J_C$ have been achieved recently with nGimat powder, $J_E(4.2K, 15T) = 1360$ A/mm$^2$ and $J_C(4.2K, 15T) = 6860$ A/mm$^2$, a 60% increase over Nexans powder.

• $J_C$ is independent of the initial filament size over the range from 9 µm to 14 µm.

• Bi-2212 can be twisted, and hysteretic loss is reduced.

• Bi-2212 is ready for magnets.
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- All Bi-2212 round wires were fabricated by Bruker-OST.

Thank you for your attention.