Improved critical current density in recent Bi-2212 round wires

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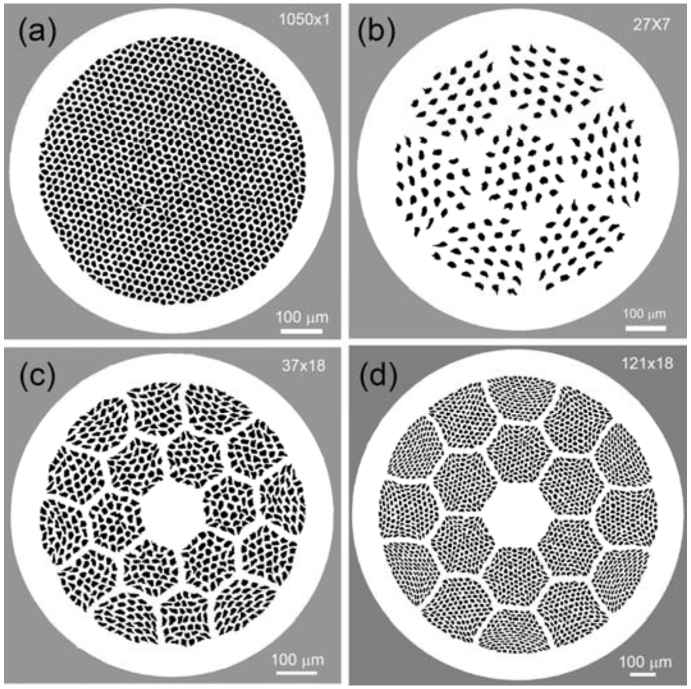
Our external collaborators

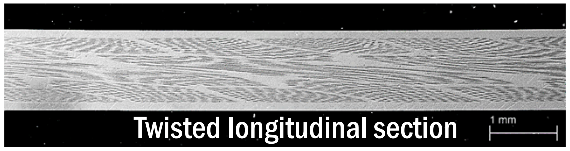
- **Yibing Huang, Hanping Miao and Jeff A. Parrell of Bruker-OST.**
- **Andrew Hunt, Marvis White, Aixia Xu and Riley Nesbit of nGimat.**
- **Suvankar Sengupta and Rao Revur of MetaMateria.**
- **Tengming Shen of LBNL.**
- **Alex Otto of Solid Materials Solutions (SMS).**
- **Other presentation at EUCAS:**
  - T. Shen, 4LO2-04, Bi-2212 Racetrack coil (this afternoon).

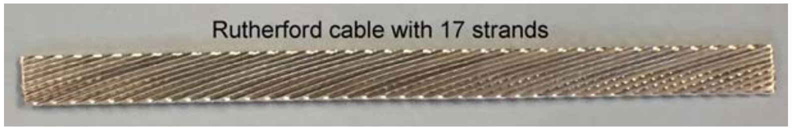
Many architectures of Bi-2212 Round Wire

- 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





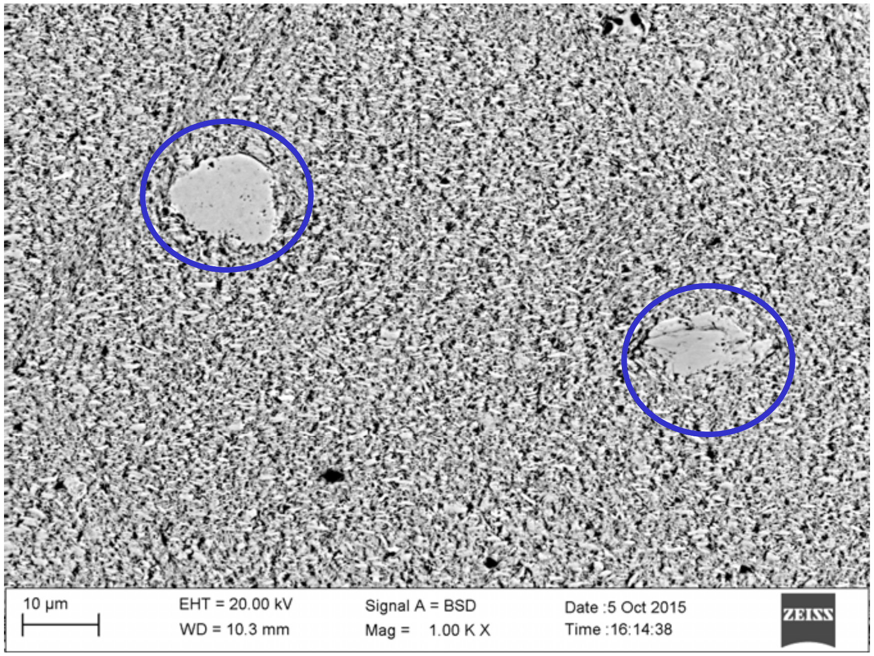
Good conductors start with good powder

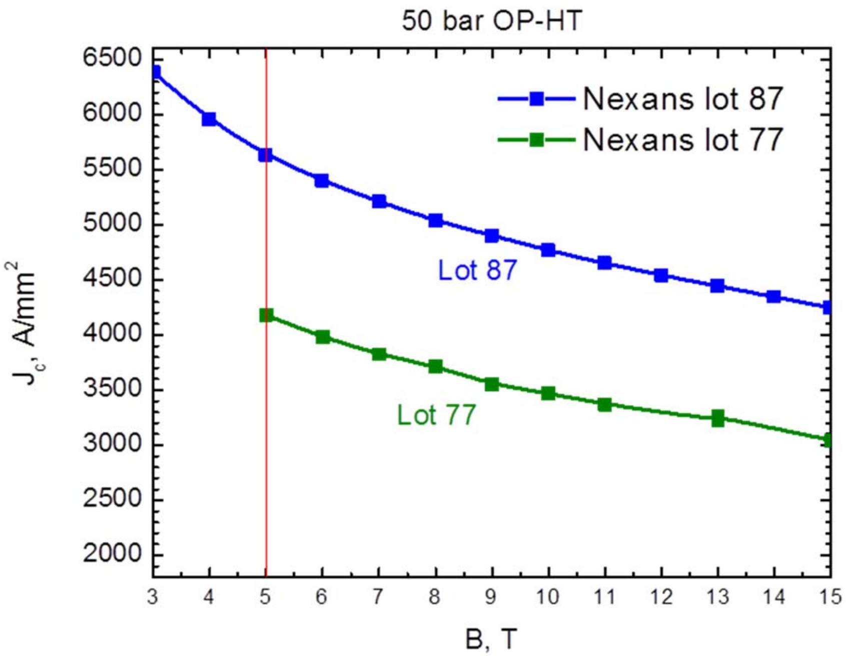
- **Composition (Nexans 521 to 524 series)**
  - **521 ($Bi_{2.17}Sr_{1.94}Ca_{0.90}Cu_{1.98}O_x$) was the best.**
- **Particle size and distribution**
  - **Issue of hard particles in Nexans lots 80 and 82.**
  - **Nexans final powder: lot 87 (the benchmark).**
- **Tap density**
- **C and H content: 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



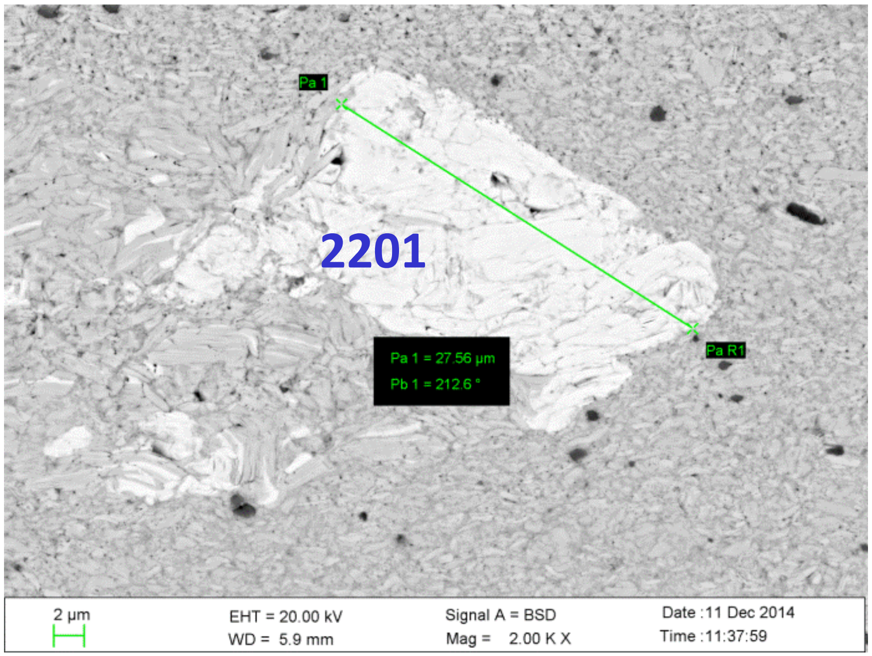


Still some hard particles with reduced size, less impact on filament merging.

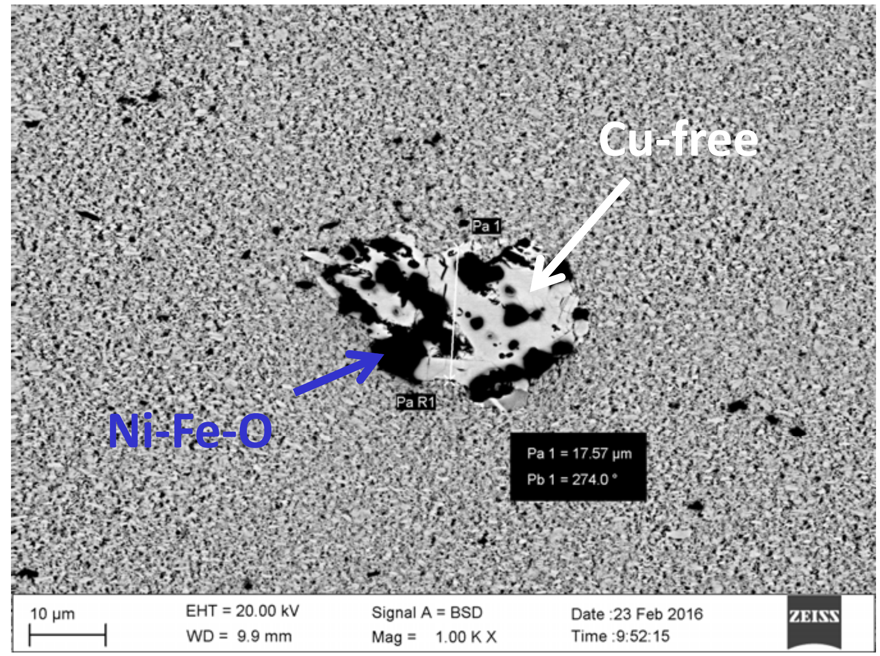
J_C(4.2K, 5T) = 5600 A/mm^2

J_E(4.2K, 5T) = 1100 A/mm^2

Earlier MetaMateria powders contain large localized Bi-2201 particles, and Al and Ni-Fe.



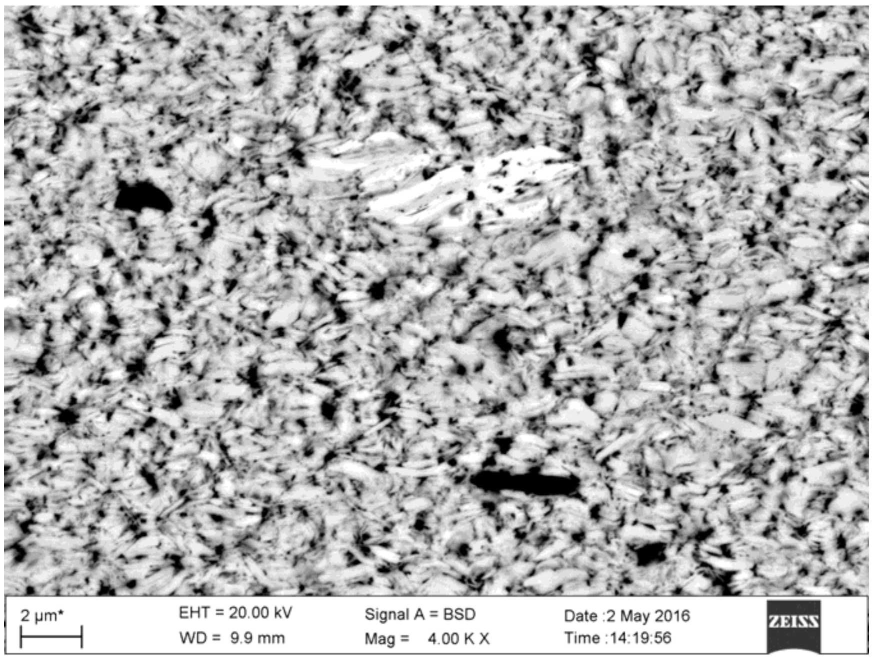
Bi-2201 particles (>20 µm)



Ni-Fe-O and Cu-free

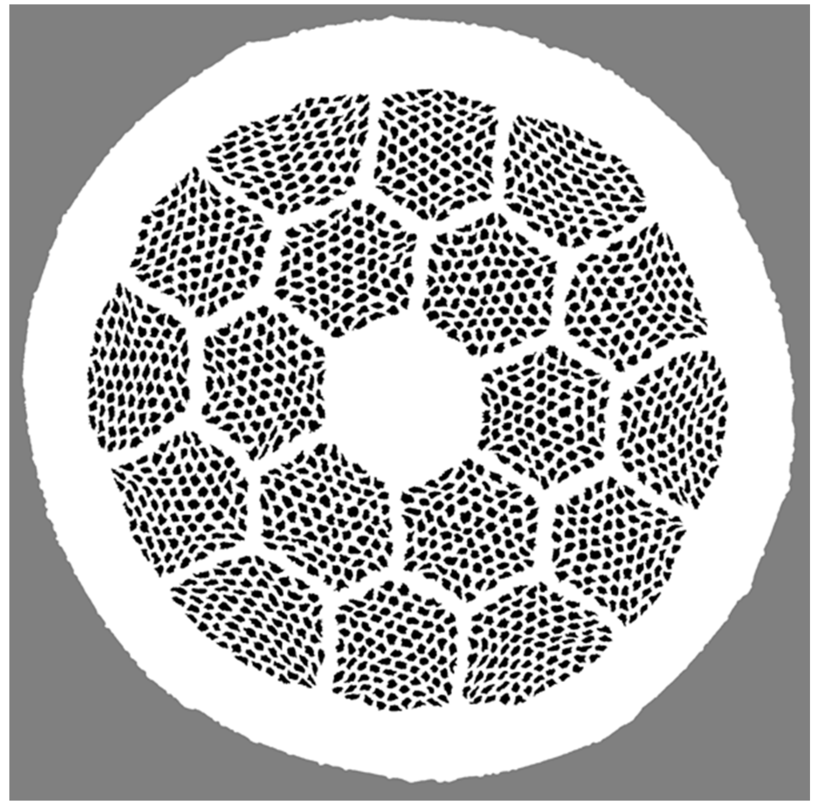
Recent MetaMateria powder has few impurity phases

Powder MM-237



Some Bi-2201

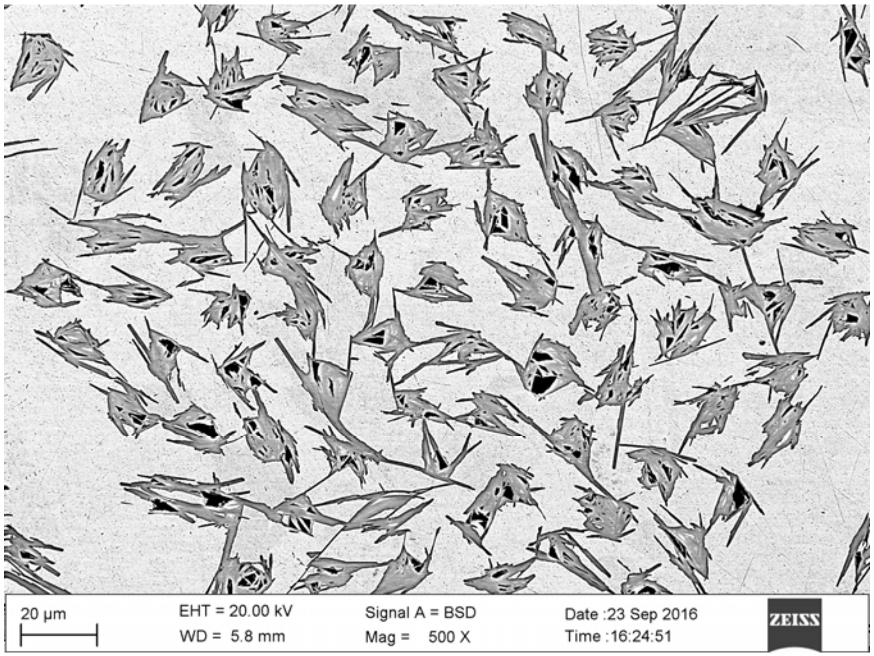
After powder densification

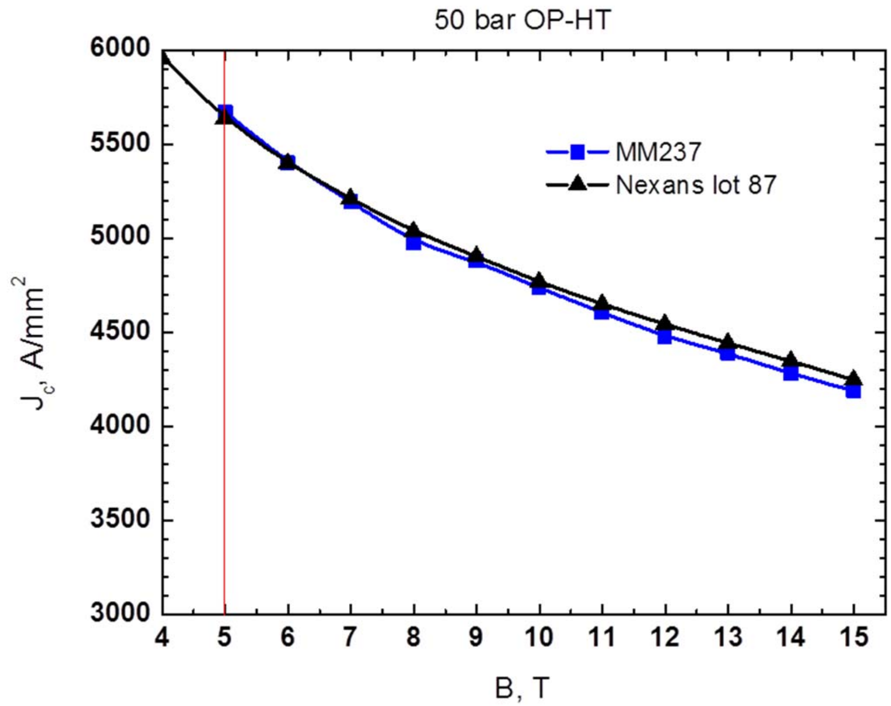


1.2 mm, FF = 0.22

New MetaMateria powder is very similar to Nexans

After 50 bar OP-HT





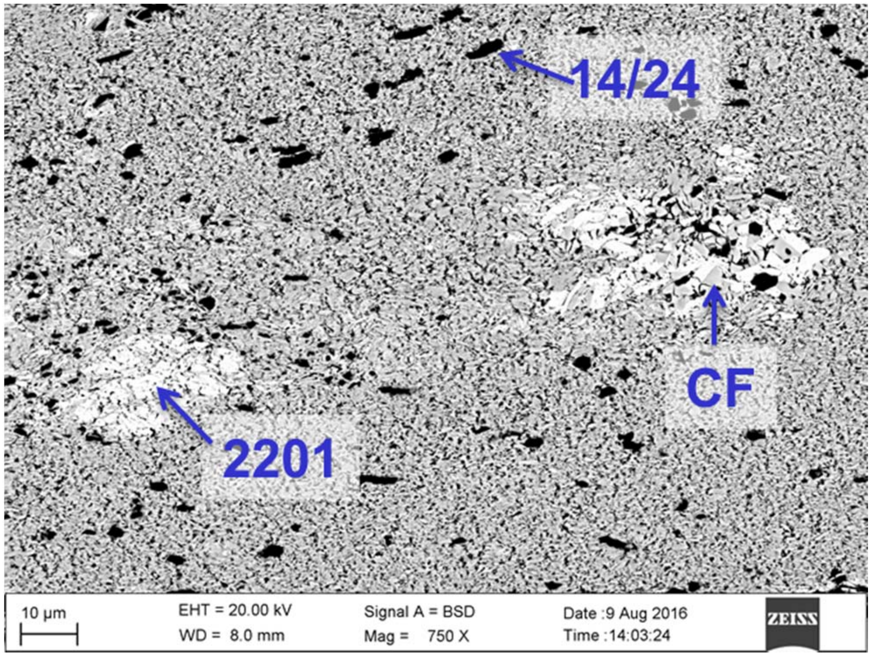
MM-237

$J_C(4.2K, 5T) = 5670\ A/mm^2$

$J_E(4.2K, 5T) = 1250\ A/mm^2$

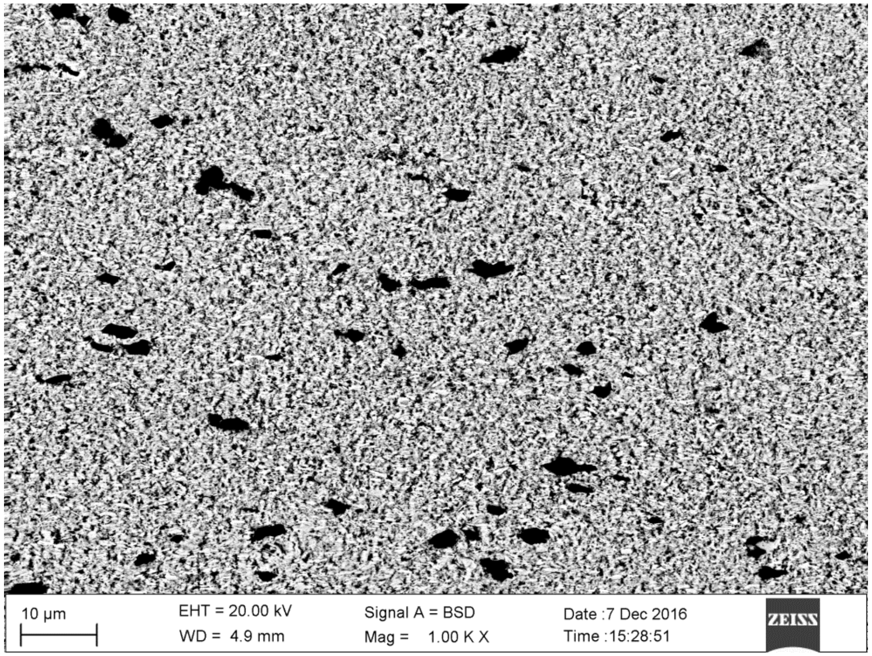
Impurity phases in nGimat powder have decreased with time

nGimat LXB-43



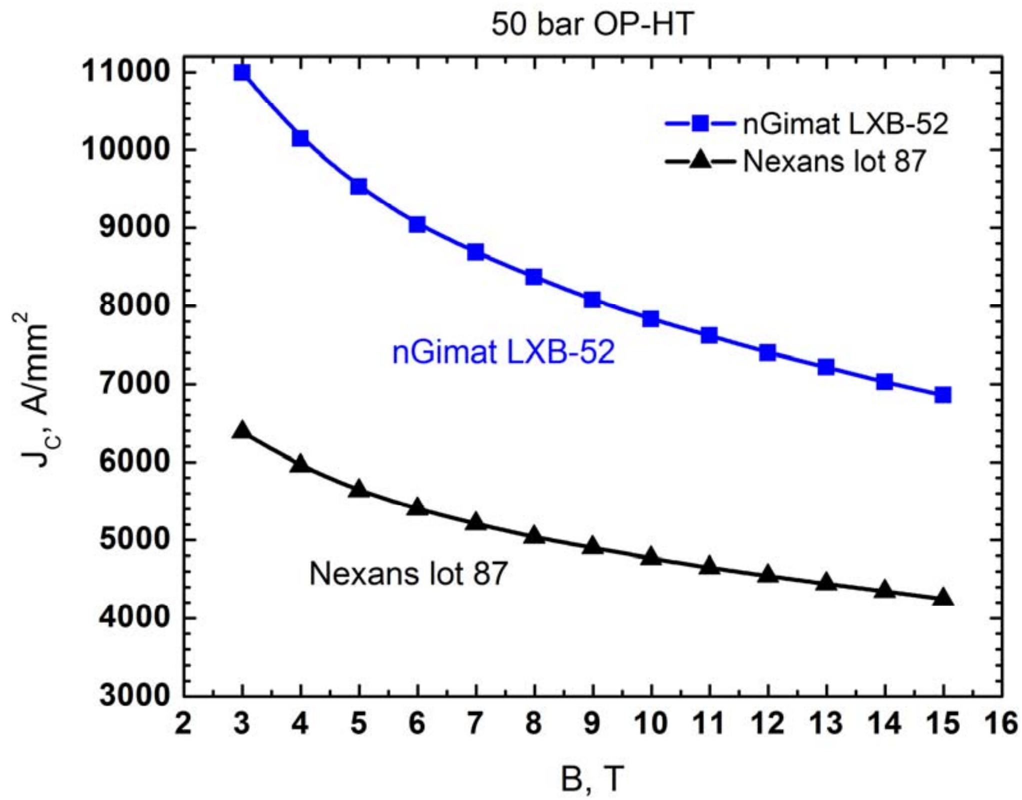
Some Bi-2201 (white), AEC-14/24 (black), and Cu-free (next to 2201)

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

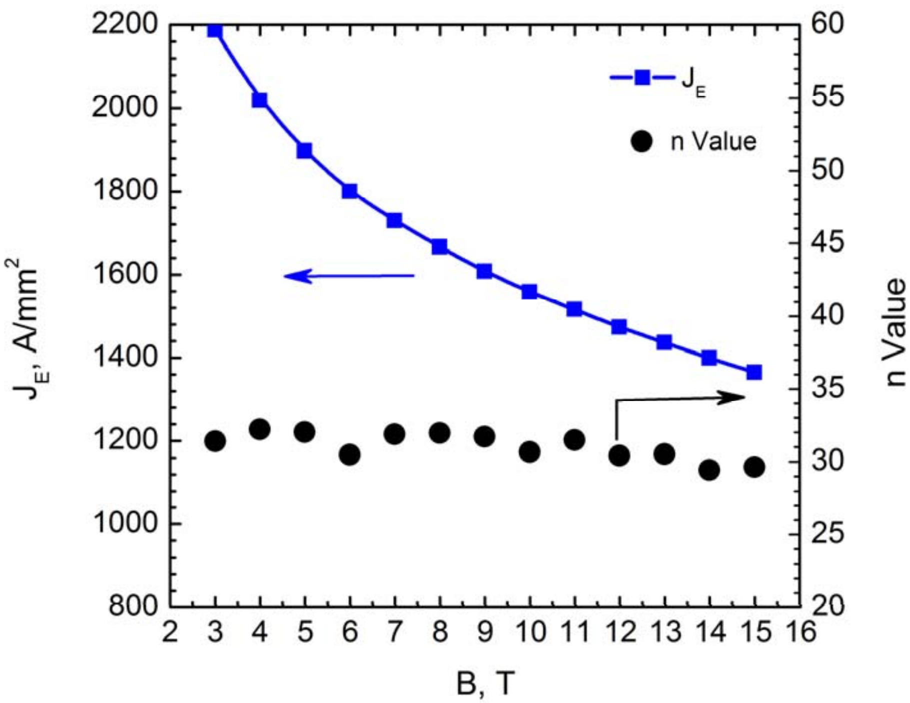


I_C(4.2K, 5T) = 914 A (0.78 mm diameter)

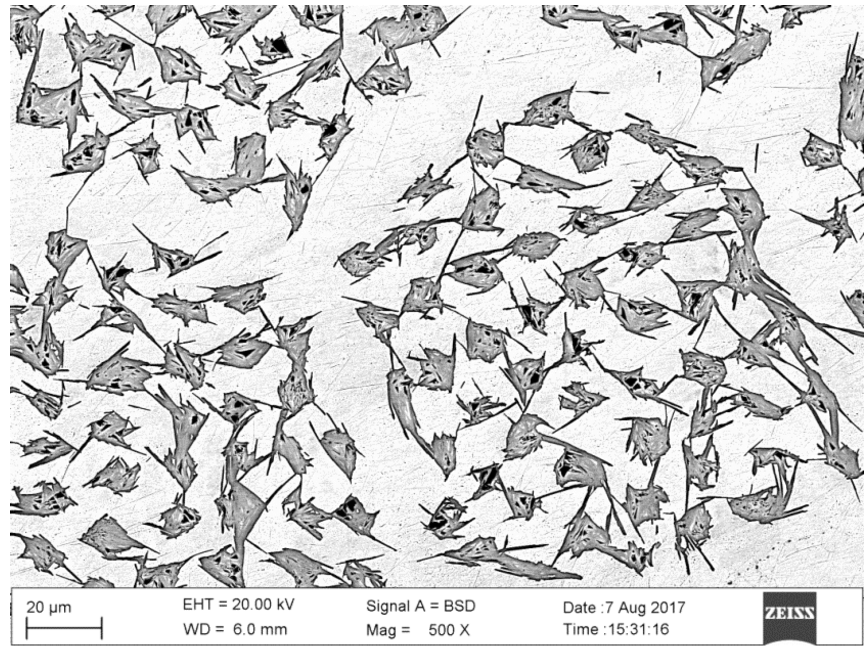
J_E(4.2K, 5T) = 1900 A/mm^2

J_C(4.2K, 5T) = 9530 A/mm^2

J_E(4.2 K, 15 T) = 1365 A/mm^2 and n of ~ 30



nGimat LXB-52



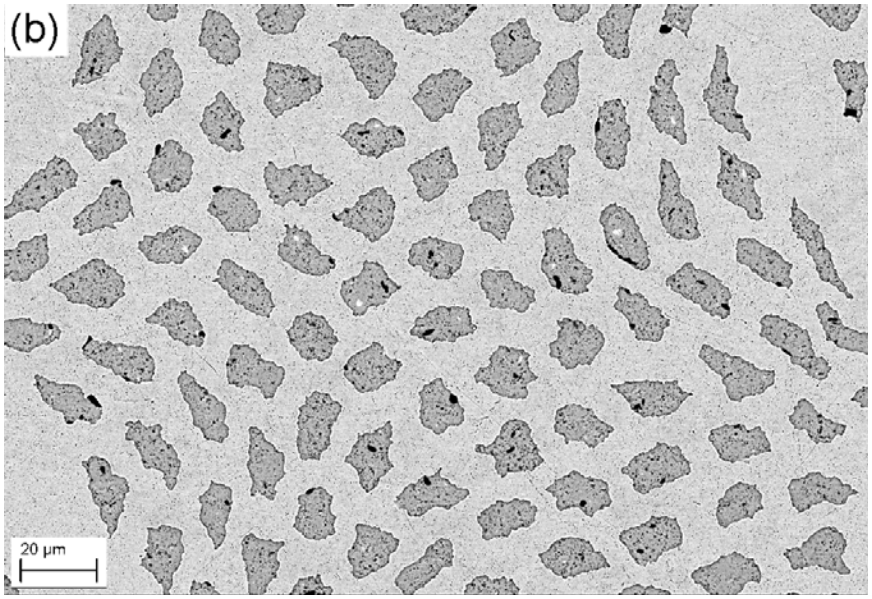
I_C(4.2K, 15T) = 658 A (0.78 mm diameter)

J_E(4.2K, 15T) = 1365 A/mm^2 (2x of FCC target)

J_C(4.2K, 15T) = 6860 A/mm^2

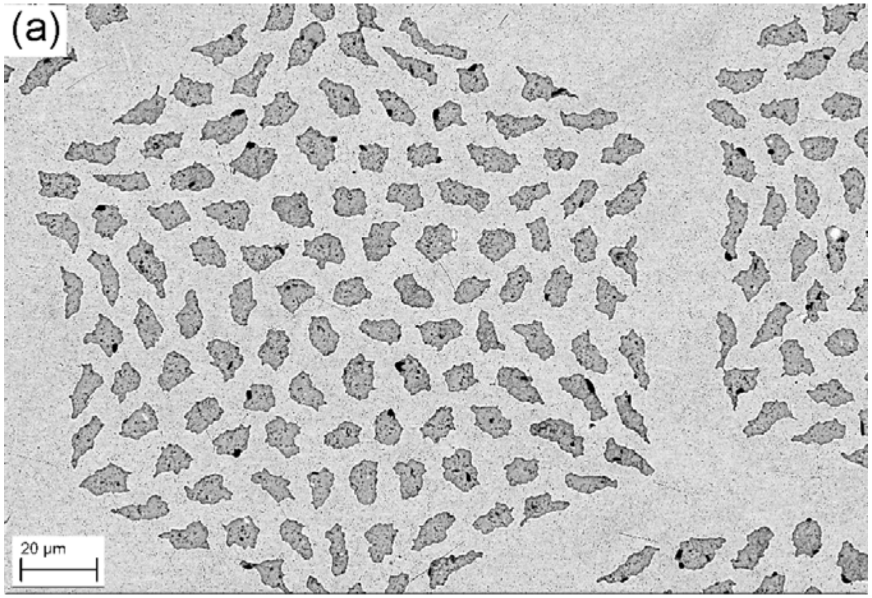
the wire drawing is excellent for different diameters wire dia. from 1.5 to 1.0 mm (Nexans lot 87)

Densified 1.4 mm wire



12.9 μm

Densified 1.0 mm wire

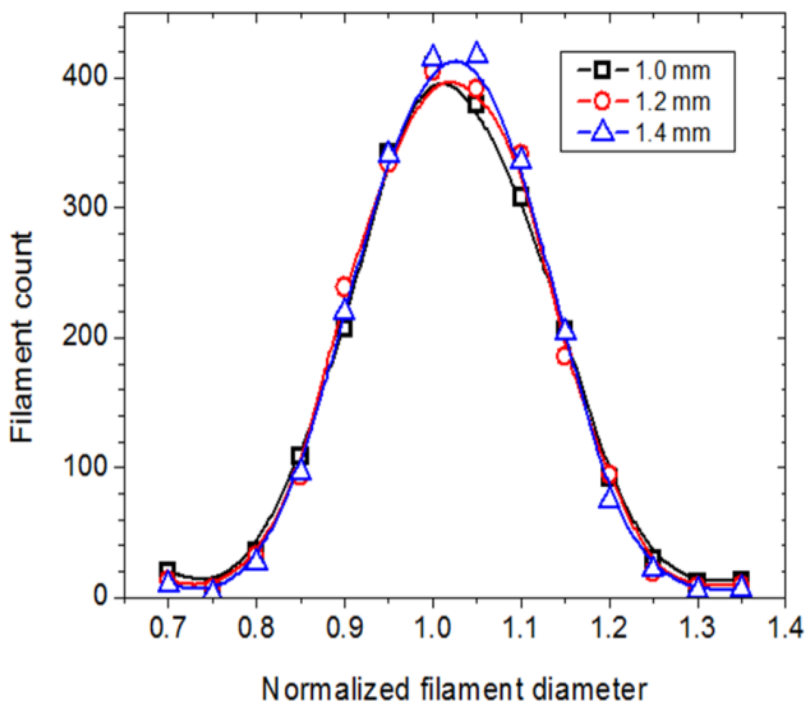


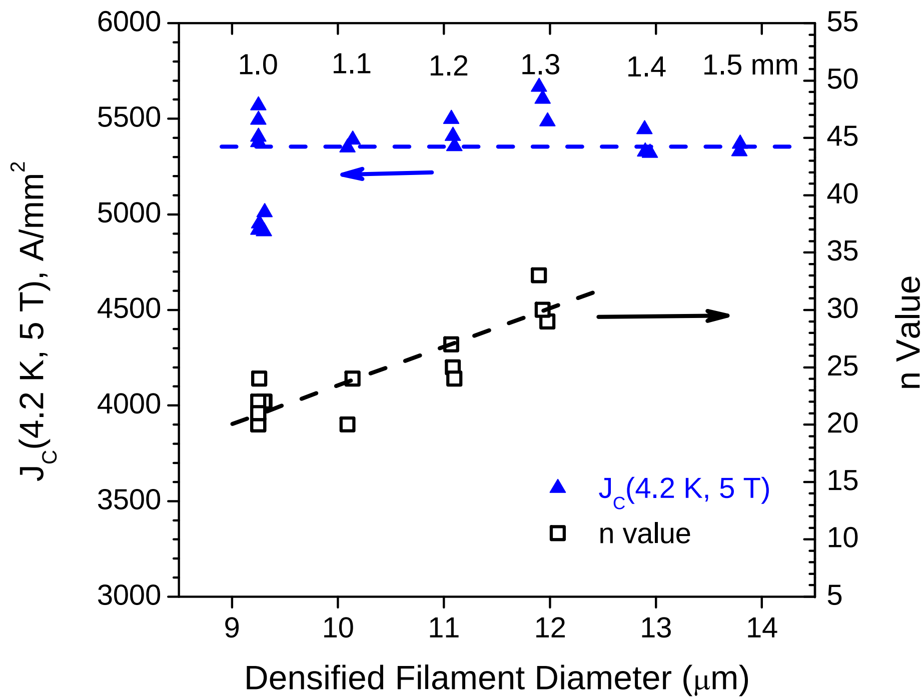
9.3 μm

Jiang *et al.*, *IEEE Trans. Appl. Supercond.*, 27, 4, 6400104 (2017)

J_C is independent of the initial filament size

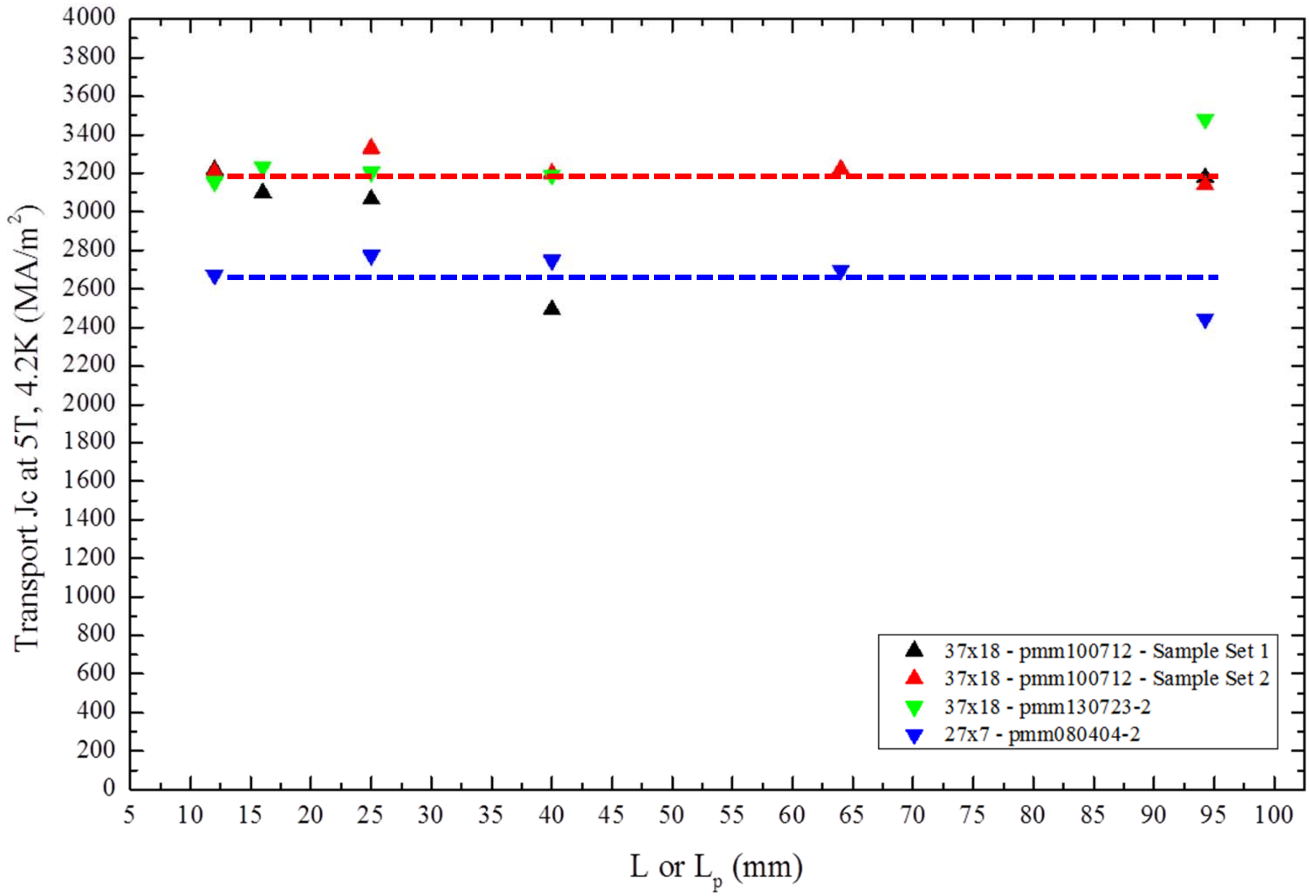
Very similar filament size distribution





Jiang *et al.*, *IEEE Trans. Appl. Supercond.*, 27, 4, 6400104 (2017)

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



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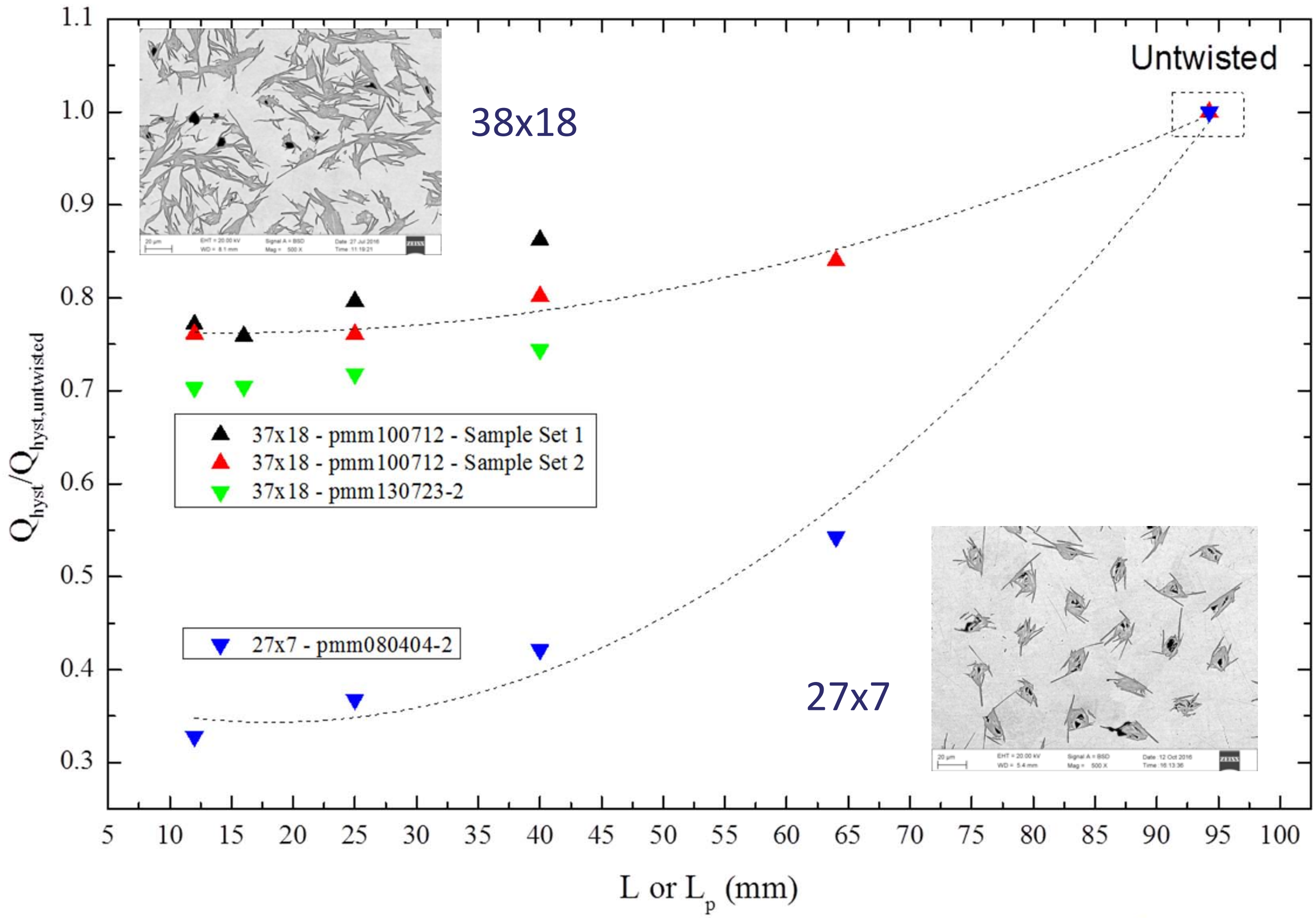
Twisting reduced losses by ~25% for 37x18 and ~70% for 27x7



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Summary

- **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.**

Acknowledgements

- **Supported by the US DOE Office of High Energy Physics under grant number DE-SC0010421, and by the NHMFL, which is supported by NSF under NSF/DMR-1157490 and by the State of Florida.**
- **All Bi-2212 round wires were fabricated by Bruker-OST.**

Thank you for your attention.