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Bi2201 Bi2212

On the roles of $Bi_2Sr_2CuO_x$ in $Bi_2Sr_2CaCu_2O_x$/Ag round wire transport on multiple length scales

ASC 2014 Best Student Paper Contest

Golsa Naderi, Evan Benjamin Callaway, and Justin Schwartz

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Outline

- Introduction on Bi2212 underlying challenges
- Results and discussions
  - Relationships between transport and filament microstructure
  - Roles of Bi2201 grains
  - Roles of Bi2201 intergrowths
  - Multiscale Bi2201 in over-pressured round wires
- Conclusions

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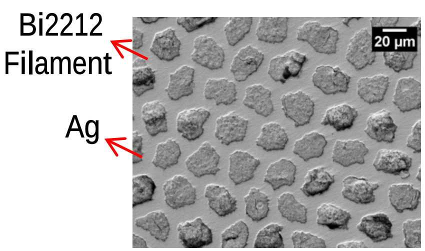
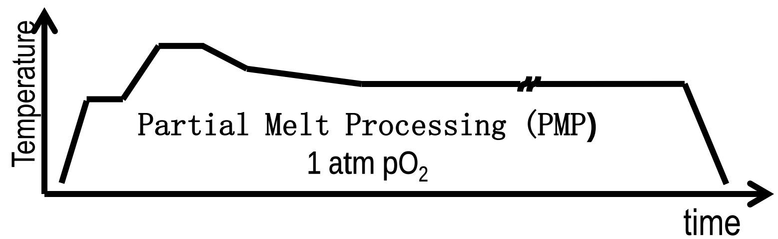
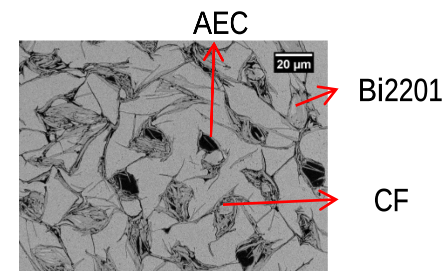
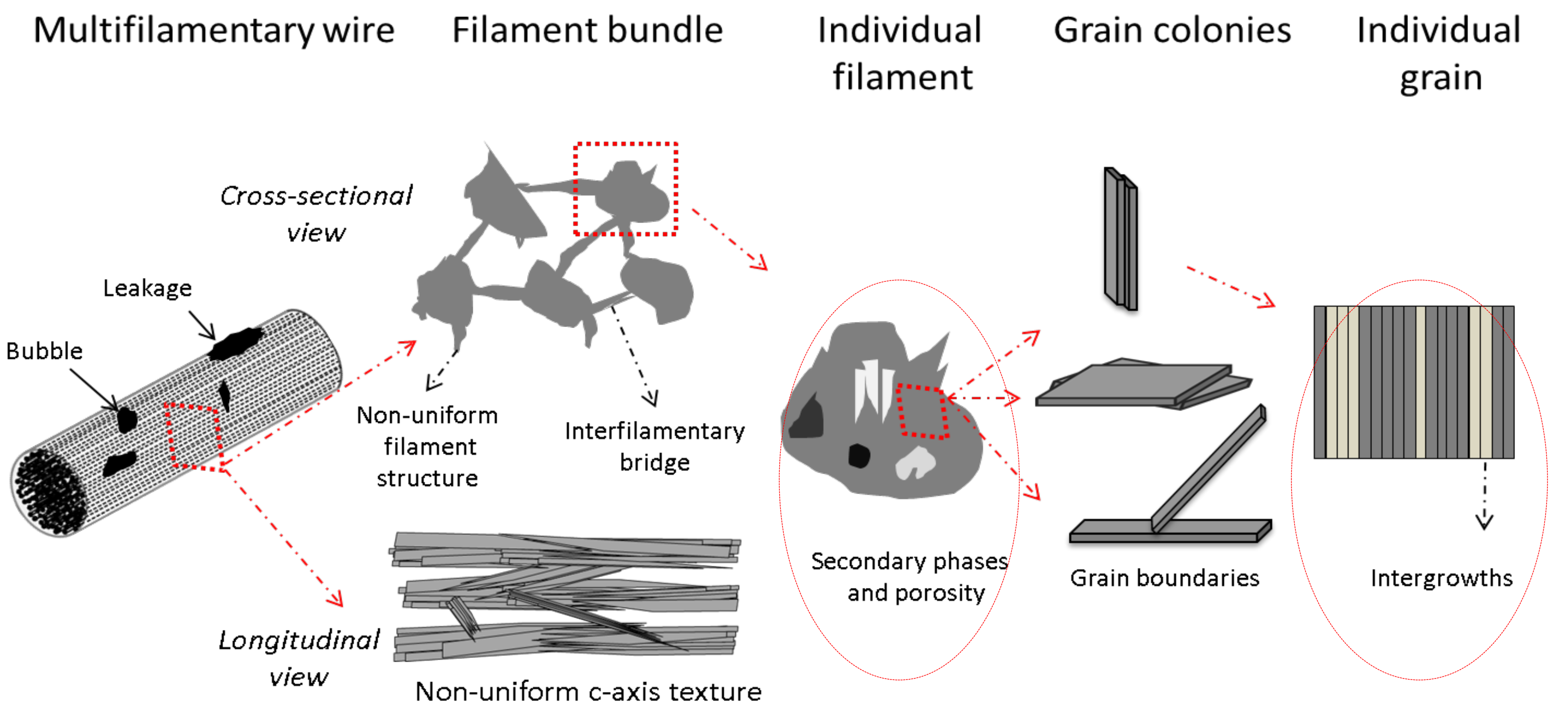
Bi2212 challenges after processing on multiple length scales

Bi2201 + **Bi2212** ⇄ **Liquid + Alkaline Earth Cuprate (AEC) + Copper Free (CF) + O_2**









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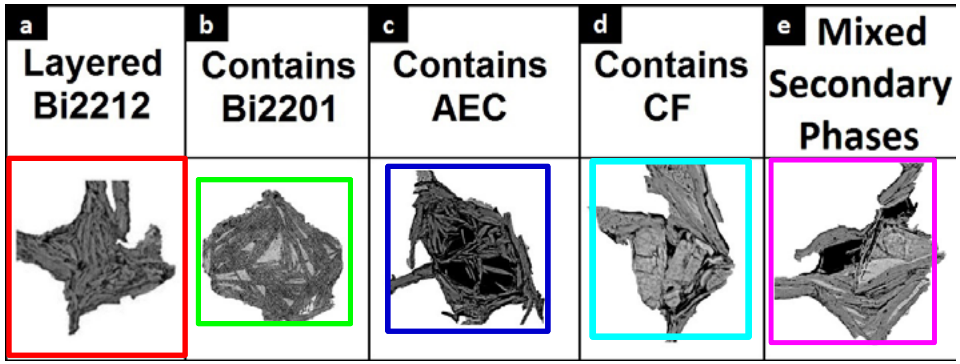
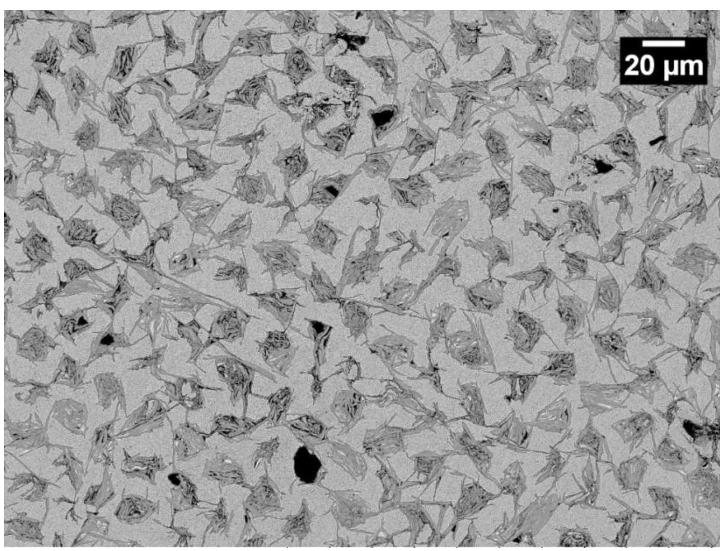
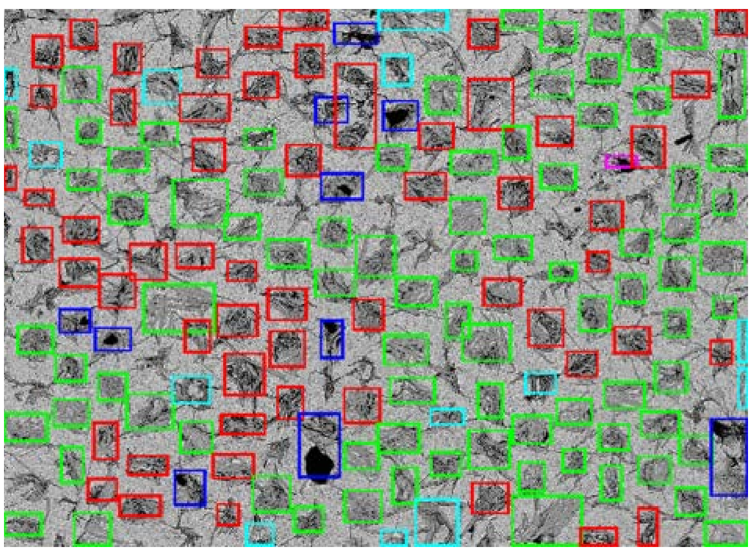
Impurities in individual filaments

Statistical analysis of filament microstructure



- A Matlab program analyzes the SEM micrographs and categorizes over 100 filaments within the image
- A total of 41 cross-sections and 5506 filaments are characterized





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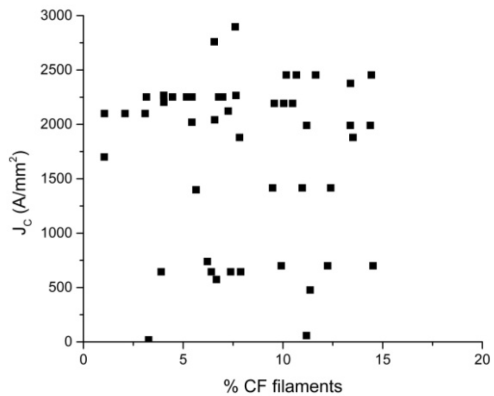
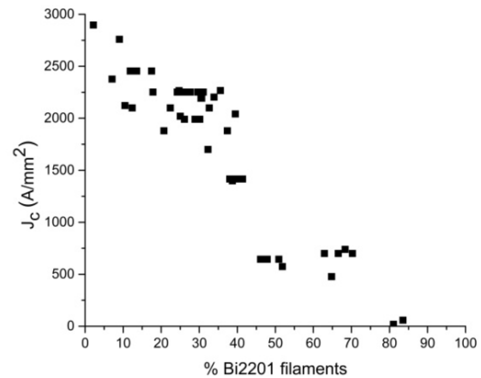
Statistical analysis of the relationship between electrical transport and filament microstructure in Bi2212

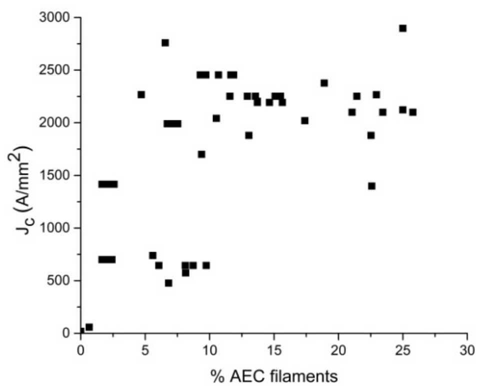
CF

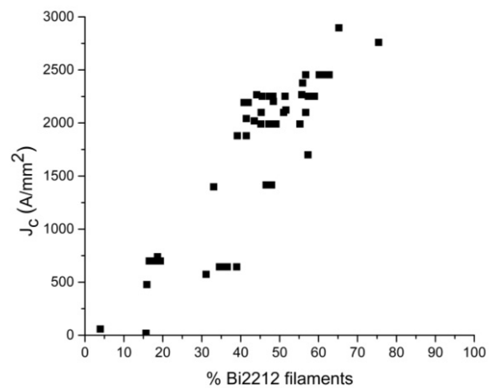




Bi2201

AEC





Bi2212

Conditions that avoid the formation of Bi2201 result in Bi2212 and AEC formation

To improve J_c:

Avoid the formation of Bi2201 grains and /or ensure conversion of Bi2201 to Bi2212

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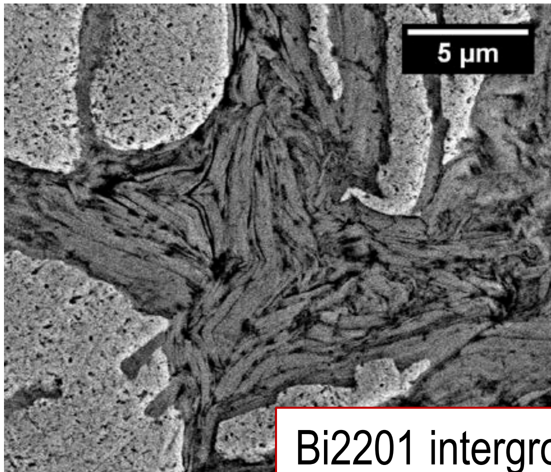
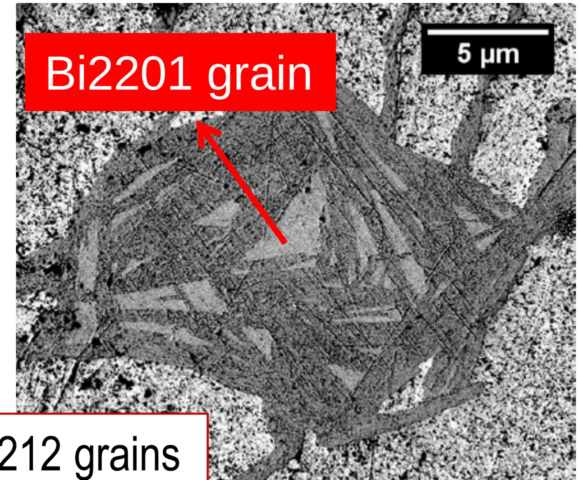
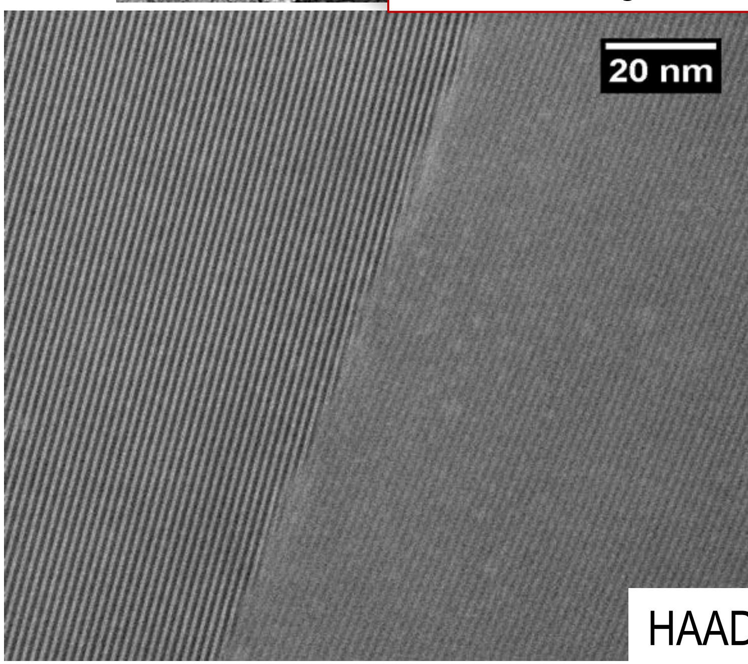
Bi2212 grains in individual filaments

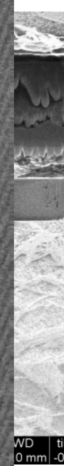
Bi2212 vs. Bi2201 filaments

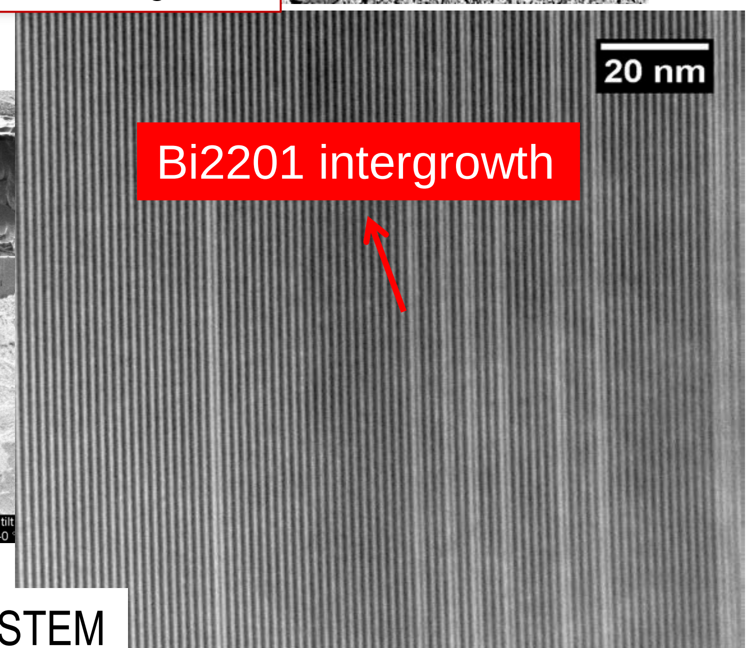




Bi2201 intergrowths in Bi2212 grains







HAADF STEM

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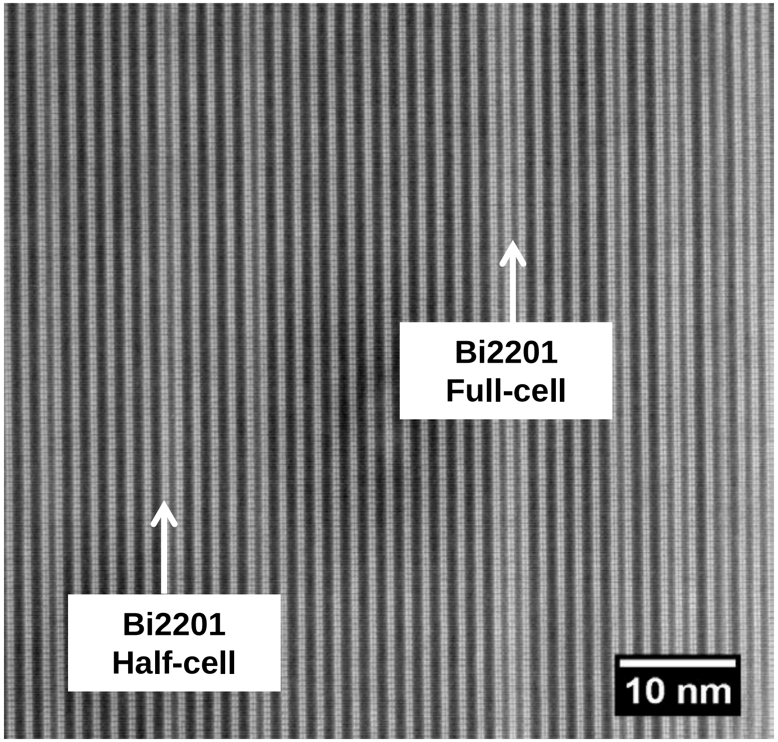
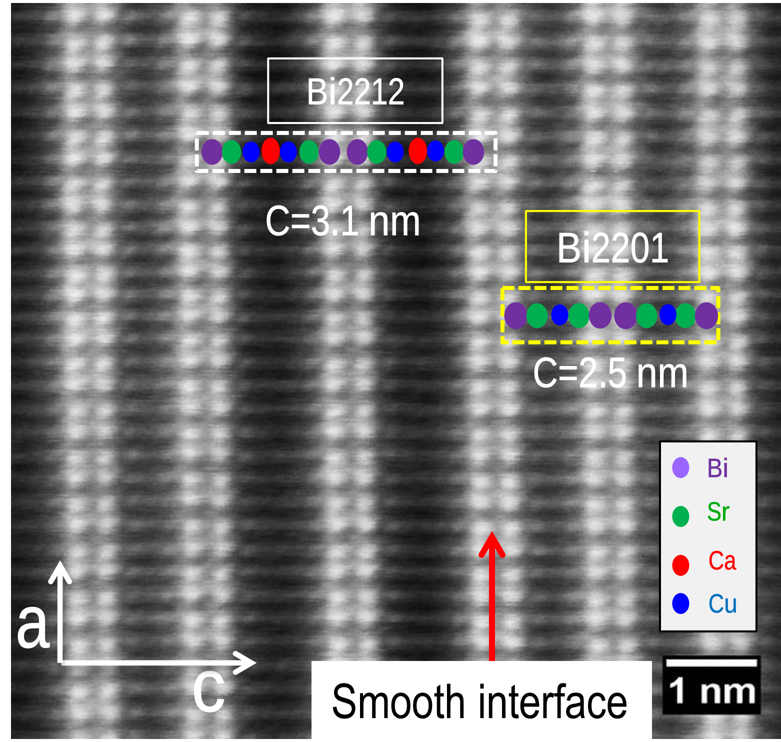
Atomic resolution HAADF STEM
Bi2212 / Bi2201 intergrowths





$\xi(4.2\ K)$ **ranges 3.09 nm – 3.07 nm**

ξ and Bi2201 half-cell and full-cell on the same order of magnitude

Intergrowths Josephson Junctions & Pinning centers ??

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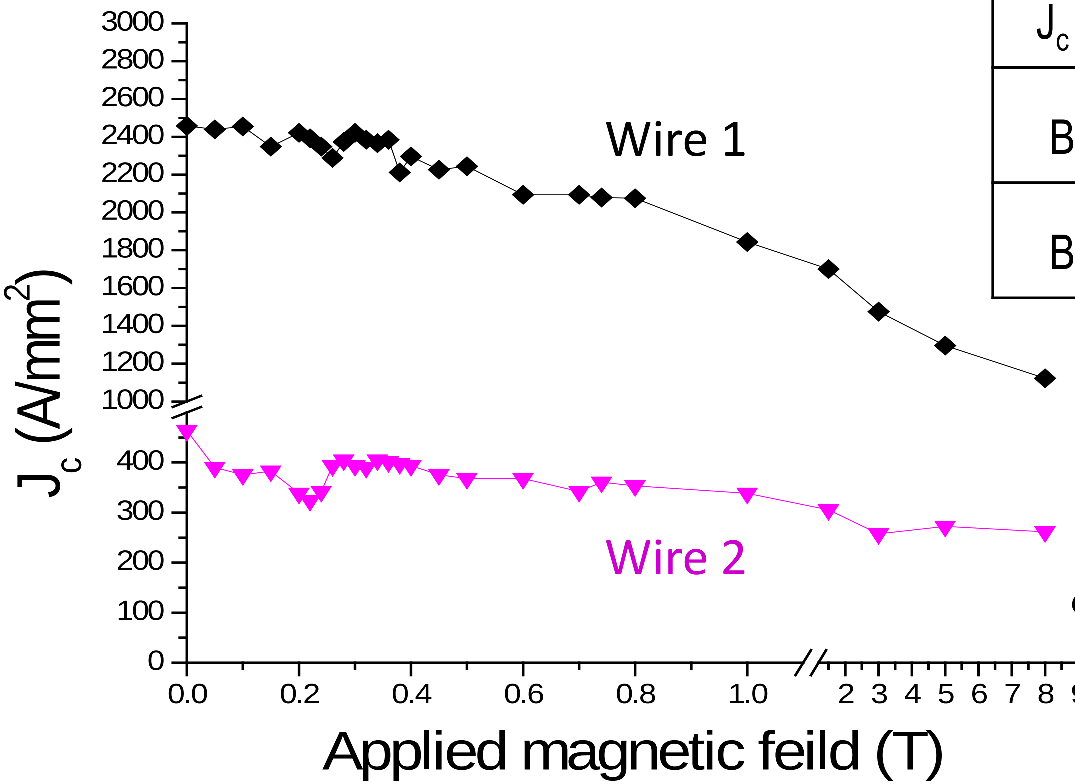
Transport magnetic field dependency to study the roles of Bi2201 intergrowths

	Wire 1	Wire 2
J_c (sf, 4.2 K), A/mm^2	2450	460
Bi2212 filaments%	60	31
Bi2201 filaments%	14	52



To distinguish weak link, Josephson Junction (JJ) & magnetic flux pinning regions

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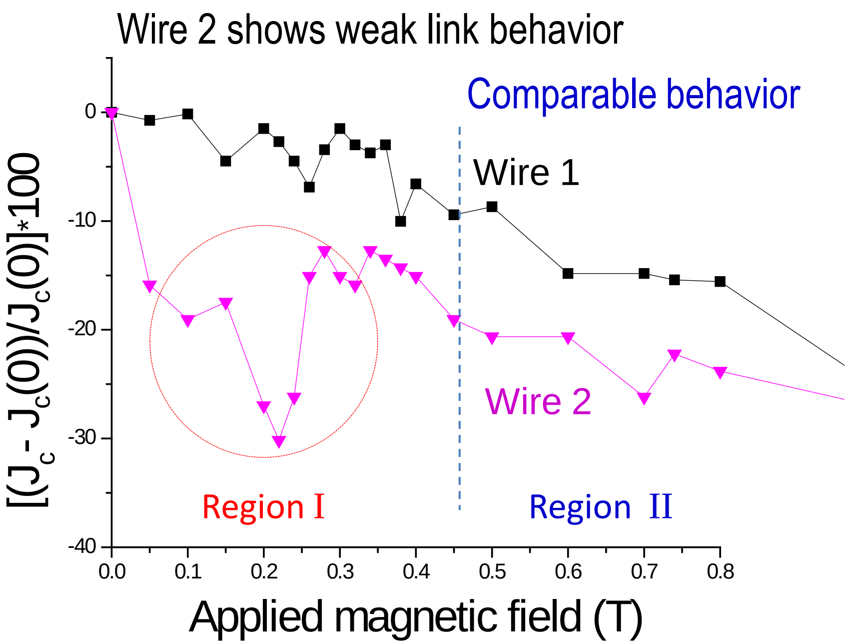
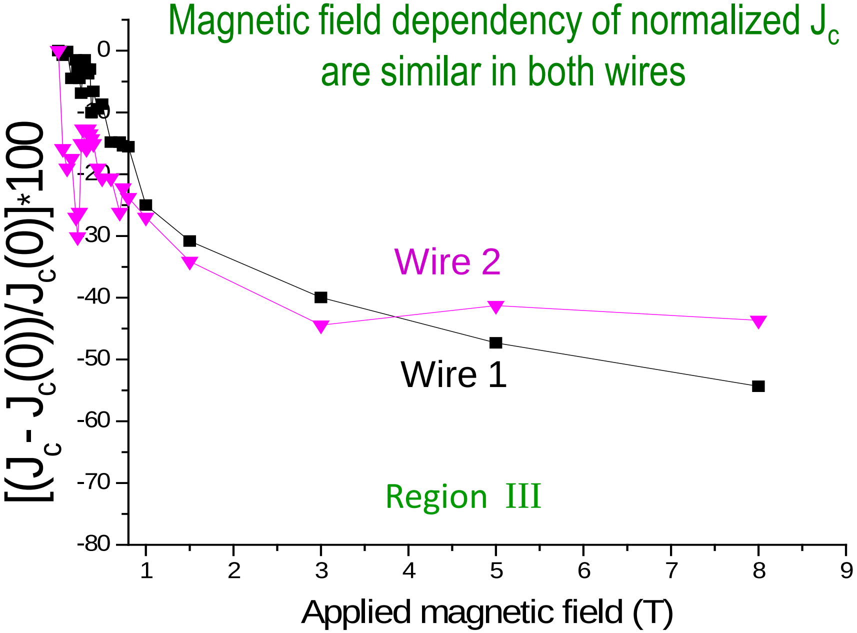
Normalized transport as a function of magnetic field to deconvolute roles of Bi2201

Weak link & JJ

Flux pinning





Bi2212/Bi2201 grain interfaces are weak links

Bi2201 half-cell & full-cell intergrowths are JJs

Bi2201 half-cell & full-cell are pinning centers

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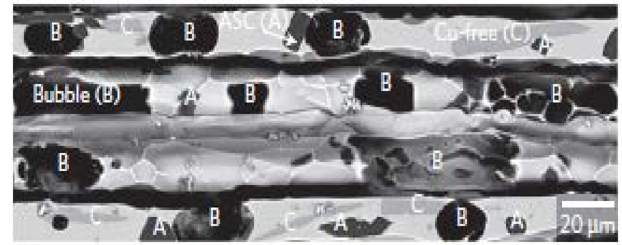
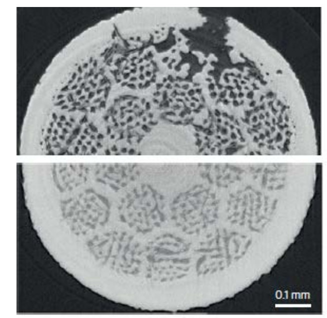
Multiscale Bi2201 in dense Bi2212 wires Over-pressure partial melt processing (OP-PMP) at the NHMFL

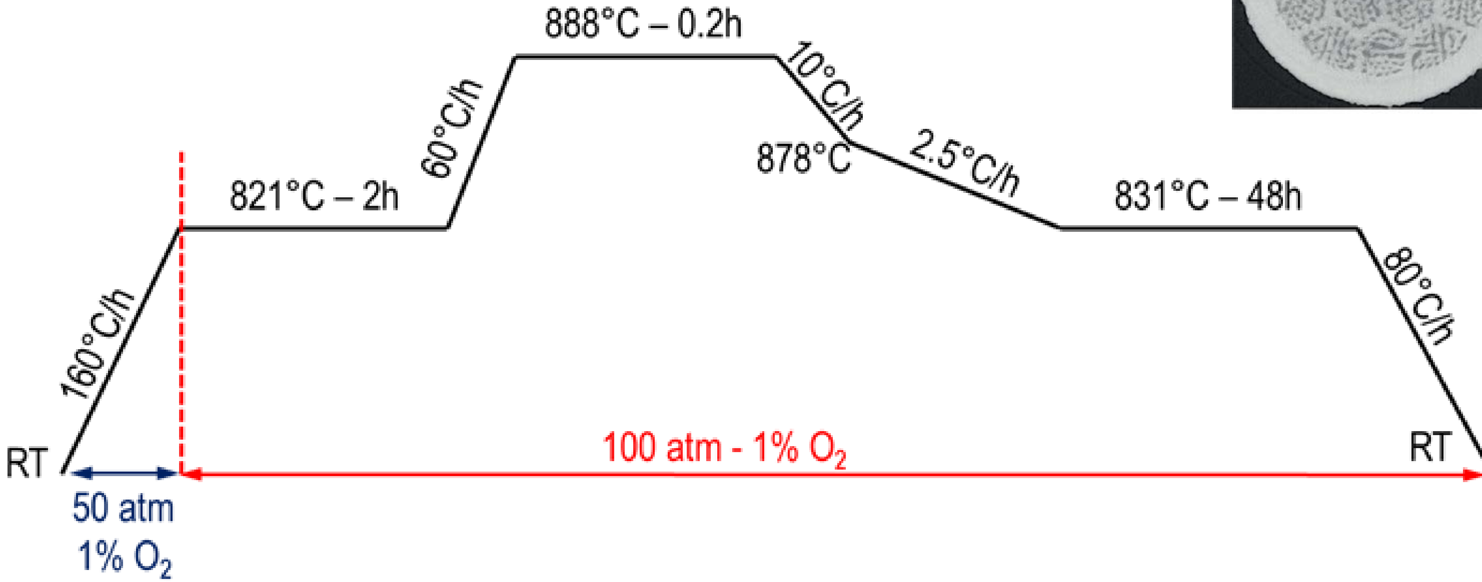
nature materials
ARTICLES
PUBLISHED ONLINE: 9 MARCH 2014 | DOI: 10.1038/NMAT3887

Isotropic round-wire multifilament cuprate superconductor for generation of magnetic fields above 30 T

D. C. Larbalestier[1*], J. Jiang[1], U. P. Trociewitz[1], F. Kametani[1], C. Scheuerlein[2], M. Dalban-Canassy[1], M. Matras[1], P. Chen[1], N. C. Craig[1], P. J. Lee[1] and E. E. Hellstrom[1]







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D. C. Larbalestier, et al. Nature Materials, vol. 13, pp. 375-381, 2014.

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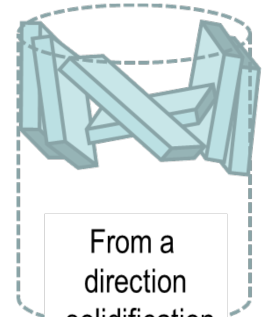
100 atm OP-PMP densifies filaments

but produces more Bi2201 filaments

From a peritectic reaction

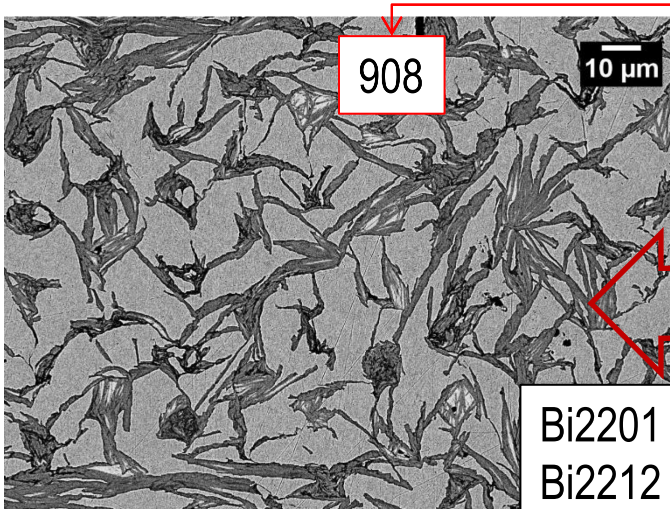
Grain growth in pre-annealing & 100 atm OP increases Bi2212 peritectic melting point

Low T_{max} relative to T_p results more Bi2201filaments



From a direction solidification

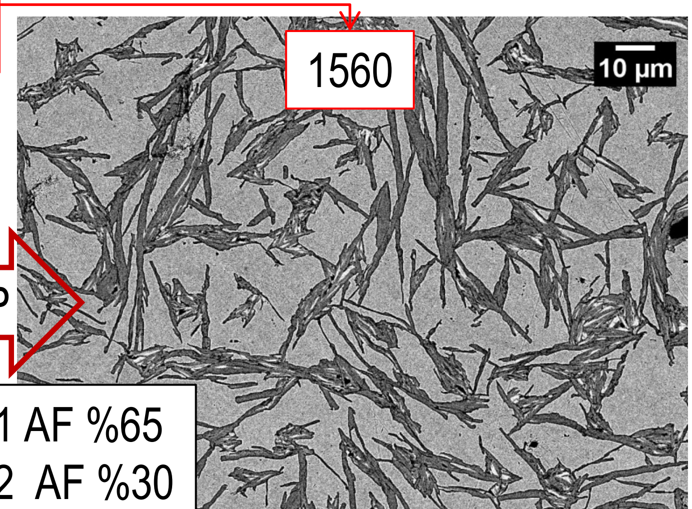
4.2 k, 5T J_c (A/mm^2)



908

PMP

Bi2201 AF %32
Bi2212 AF %61



1560

OP-PMP

Bi2201 AF %65
Bi2212 AF %30

With reducing Bi2201 filament content J_c will increase further

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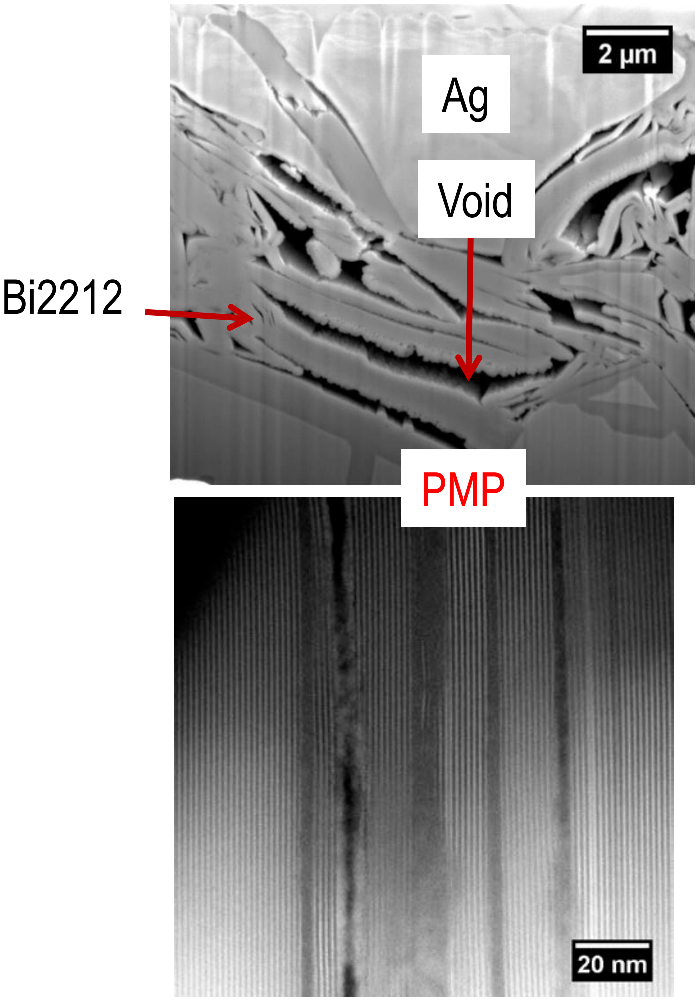
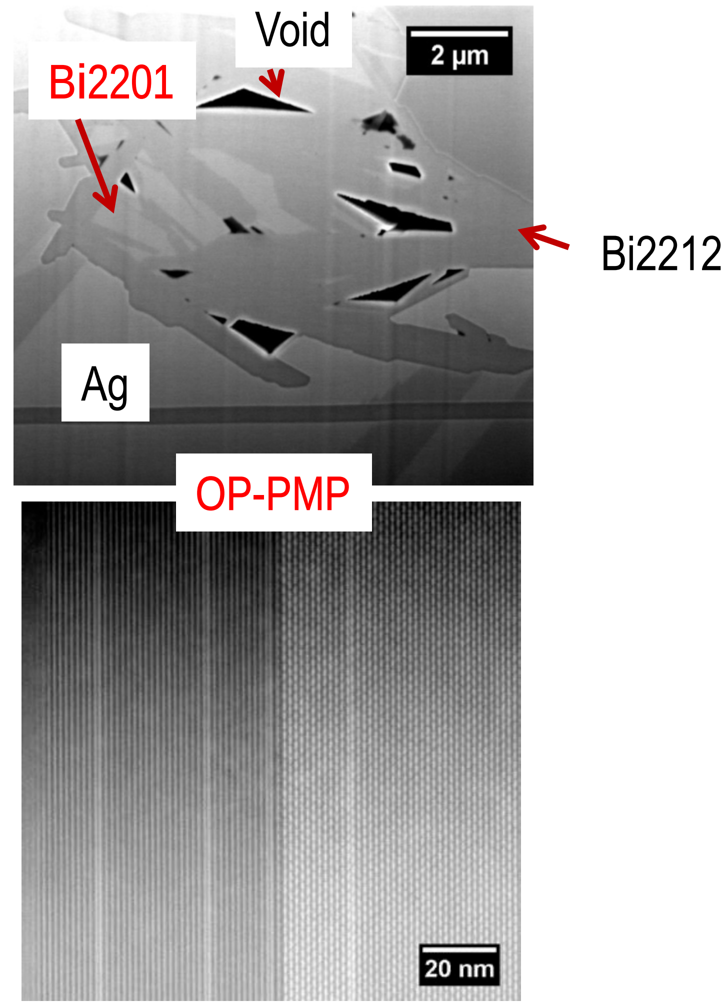
Multiscale OP-PMP densification





OP densifies both micron and nanoscale, improves intragrain connectivity
However forms more Bi2201 grains

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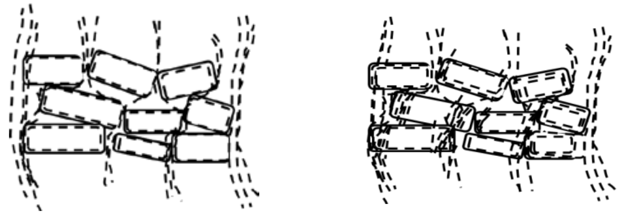
Oxygen content, Intergrain and intragrain connectivity of PMP & OP-PMP

No significant difference in overall oxygen content

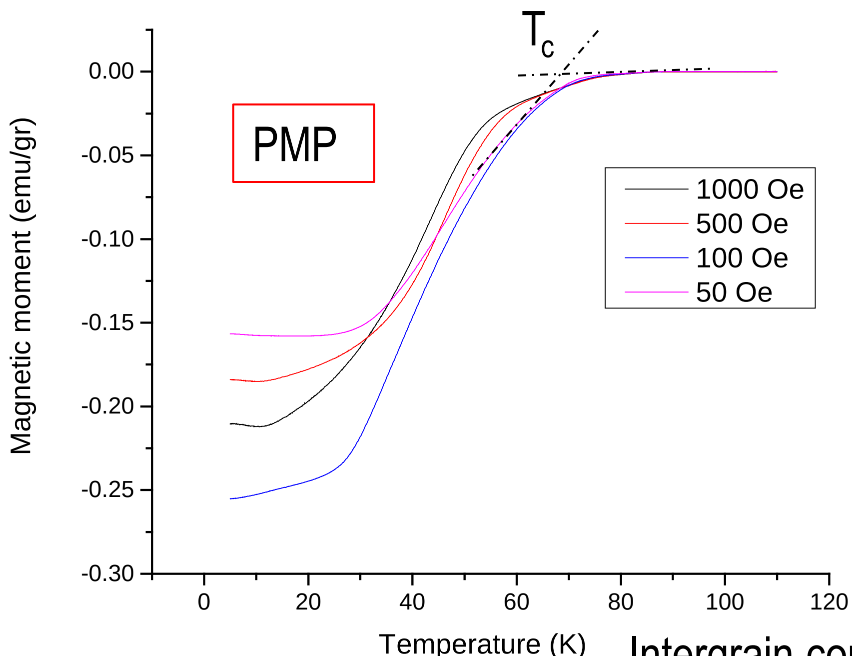
$H_{C1}^{w} < H_a < H_{C1}^{G}$ $\quad$ $H_a > H_{C1}^{G}$

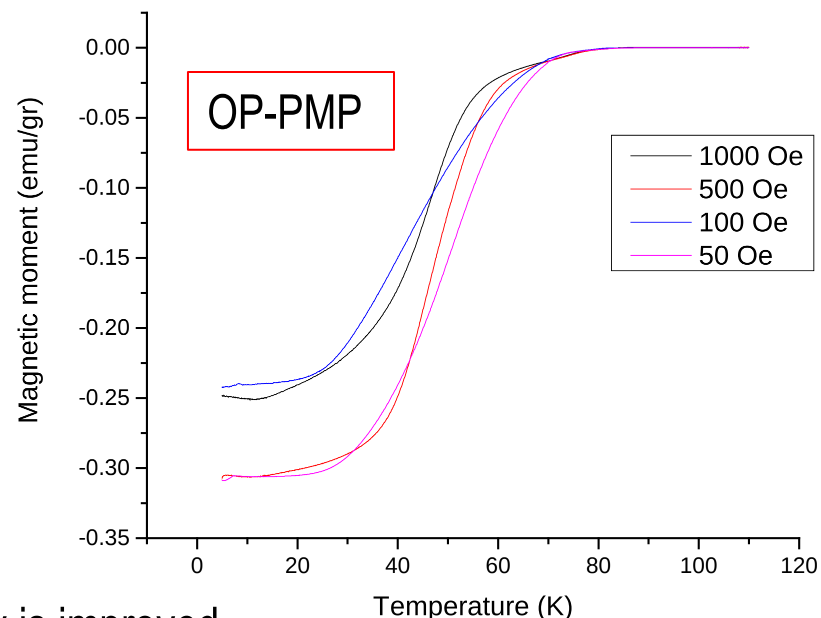


At 50 Oe, intergrain dominates OP-PMP shows much stronger magnetic moment

Above H_{C1}^{G} the grain size and pinning mechanisms determine the magnetization

At 100 Oe (H_{C1}^{G}) both wires show the similar magnetic moment





Intergrain connectivity is improved

No significant change in intragrain connectivity

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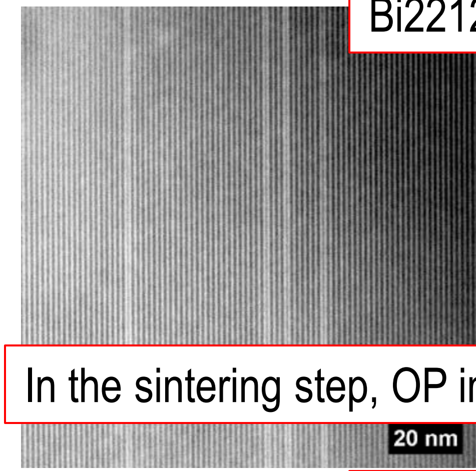
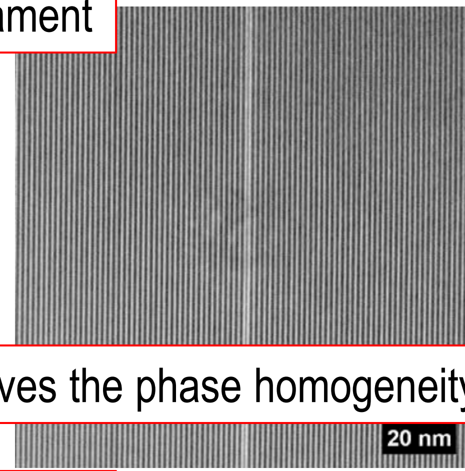
To study the intragrain structures
(HAADF-STEM) & semi-quantitative EDS

Bi2212 Filament

	at.%	Standard deviation
Bi	22.2	2.01
Sr	20.3	1.20
Ca	6	0.56
Cu	19.8	0.77
O	32.3	2.99





	at.%	Standard deviation
Bi	21.7	0.39
Sr	20.2	0.41
Ca	5.8	0.30
Cu	21.6	0.53
O	30.4	1.2

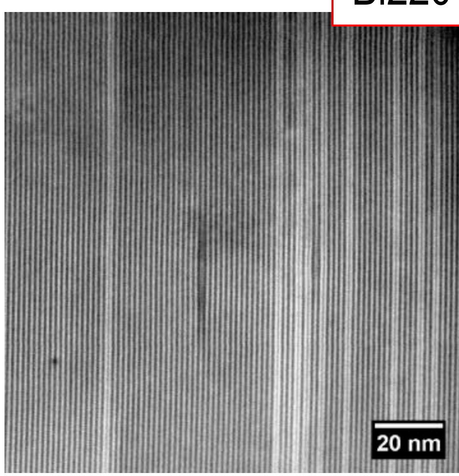
In the sintering step, OP improves the phase homogeneity

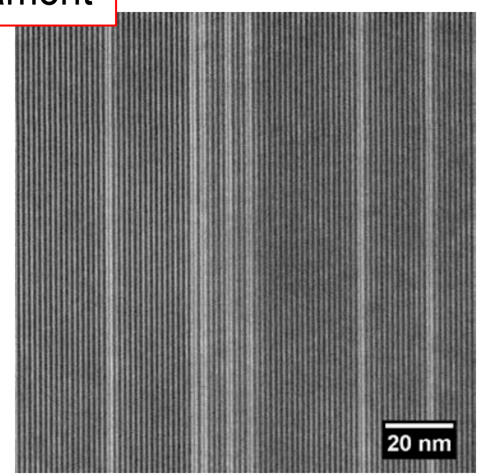
PMP

OP-PMP

Bi2201 Filament

	at.%	Standard deviation
Bi	19.9	0.95
Sr	17.8	0.79
Ca	6.3	0.45
Cu	19.7	1.25
O	36.2	3.20





	at.%	Standard deviation
Bi	18.0	0.48
Sr	16.0	0.70
Ca	6.8	0.29
Cu	18.7	0.55
O	40.2	1.95

Bi2201 filaments contain higher oxygen content than Bi2212 filaments

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Conclusions

- The primary impurity in partial-melt processed in Bi2212 wires is Bi2201, which forms as mesoscopic grains and nanoscopic intergrowths.
- Future improvements in Bi2212 wires require the elimination of Bi2201 grains.
- Half- and full-cell Bi2201 intergrowths show Josephson-Junction-like behavior at low field and flux pinning at higher field, so they are beneficial and non-detrimental to transport.
- OP-PMP increases Bi2212 filament density, improves intergrain connectivity, and consequently enhances J_c; however, with the present profile it also produces more Bi2201 grains.
- We predict that with elimination of Bi2201 filaments J_c will increase further in OP-PMP wires

Acknowledgments

- NCSU Analytical Instrumentation Facility (Dr. Xiahan Sang)
- Supercon, Inc.
- National High Magnetic Field Laboratory

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Thank you!!

Questions, comments ???