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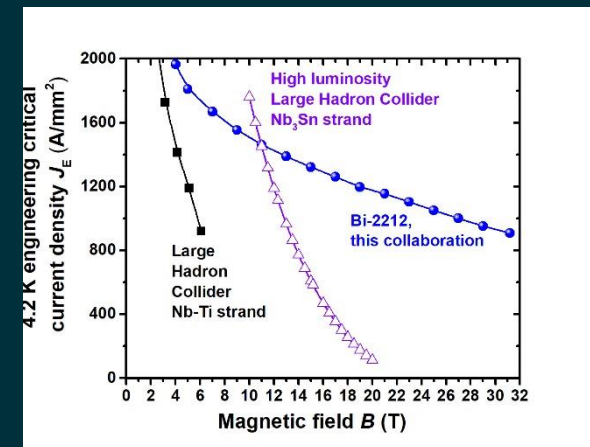
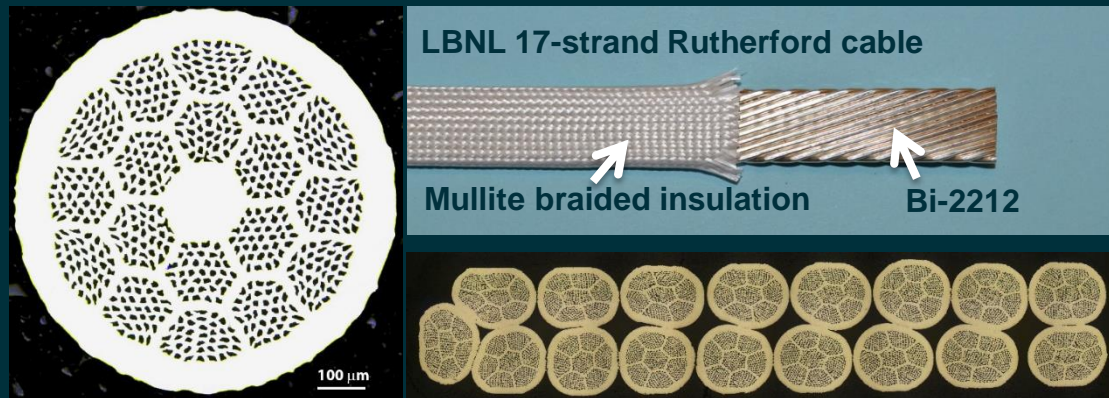
U.S. DEPARTMENT OF  
**ENERGY**

Office of Science

# ARDAP - Enhancing Domestic Production of High Temperature Superconducting $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_x/\text{Ag}$ wires for High Field Magnets

Tengming Shen

With the project team

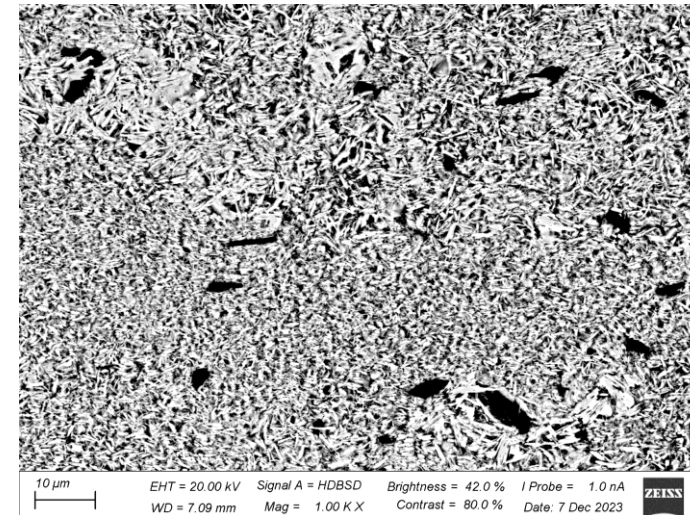
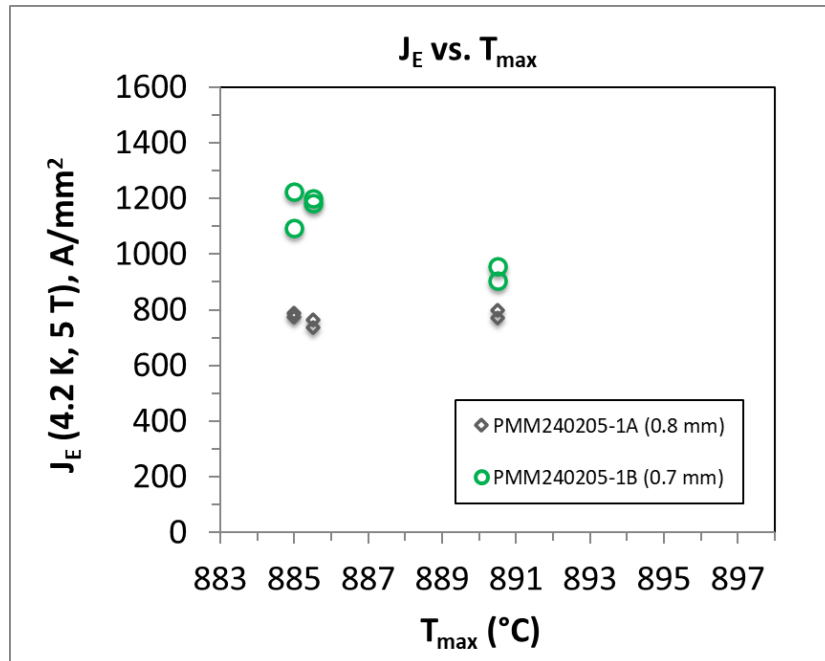


2024/10/10

# [Task 2] First billet – production and QA plan

- 500 m, in two pieces, received @ LBNL.
- Powder is G2A-07A\_HS

## G2A-07A\_HS



(Potential end effect in this set of samples)

# Cable 2007 produced with ARDAP billet #1

Project	Materials	Number of strands	Strand diameter (mm)	Cable dimensions (mm) (minor/major edge x width)	Keystone Angle (degree)	Pitch angle (degrees)	Overall packing factor (%)	Length (m)
ARDAP cable 2007A	2212	6	0.7	2.35 x 1.22	0	12	82.3	The rest
ARDAP cable 2007B	2212	6	0.7	2.35 x 1.16	0	12	86.6	8
ARDAP cable 2007C	2212	6	0.7	2.35 x 1.12	0	12	89.7	8

- **Planetary actions: -1. No wire twisting during cabling.**
- **5 m of 2007A stays at LBNL and all others shipped to NHMFL.**



## [Task 2] Second billet – production

- Powder sent to Bruker OST on March 7<sup>th</sup>.
- 510 m, sent to LBNL and received on 05/13/2024.
- Cabling in May, after the QA/QC tests, OPHTs,  $I_c$  measurements, and microscopy.
- Jianyi report  $I_c$  on 2024/06/06 and have more.

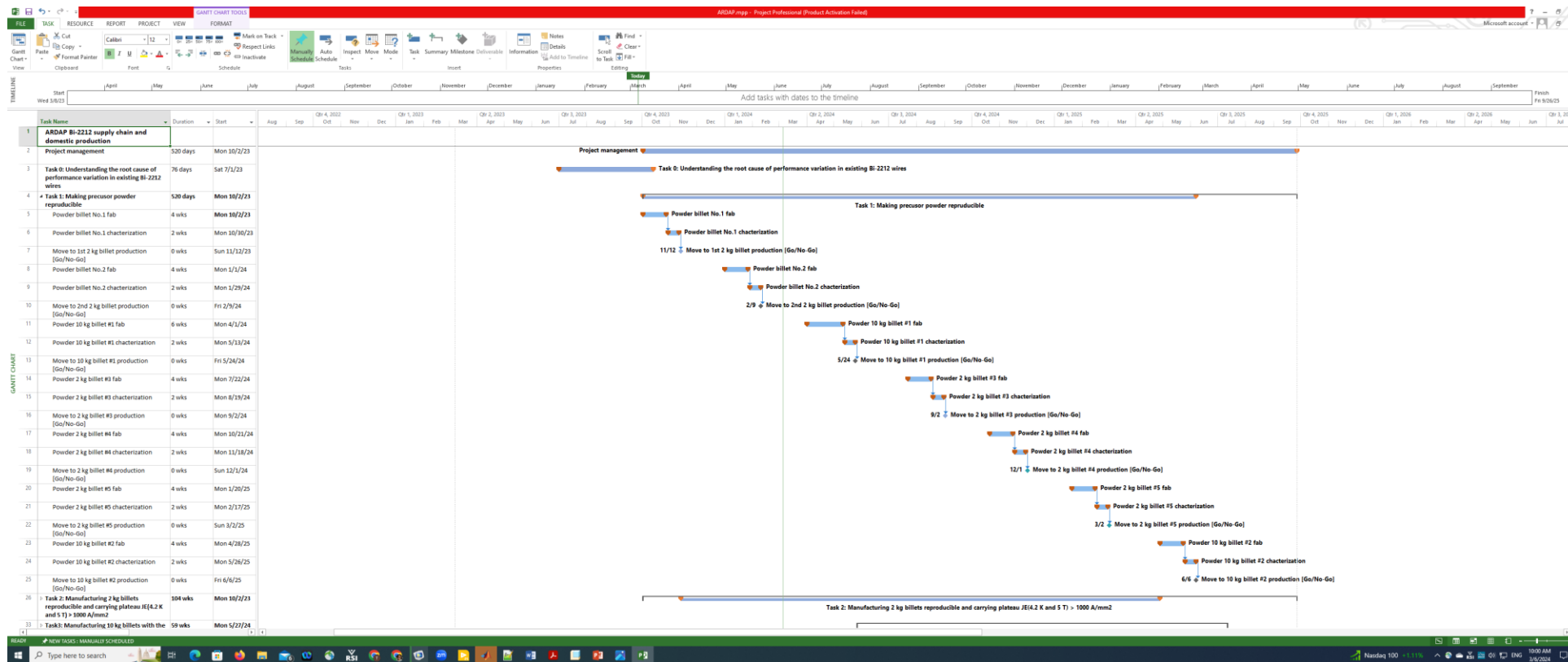
## Cable fabrication

ARDAP wire	Wire ID	Wire diameter (mm)	Wire length	Cable
#1	PMM240205	0.7	210	6-strand Rutherford cables
		0.7	295	
#2	PMM240325	0.7	510	

- 210 m -> 60 m for short sample measurements (ITER barrel measurements and others), and two spools with 73 m pieces (and additional 2 m left).
- 295 m -> 4 pieces of 73 m, and then 3 m left.
- 510 m strand #2 -> 30 m to NHMFL (DD request; Emar Martin (RIKY); IR 60 mm OR – 65 mm, height – 12.5 mm); 80 m per piece now for six spools.

# [Task 2] Third billet – production and QA plan

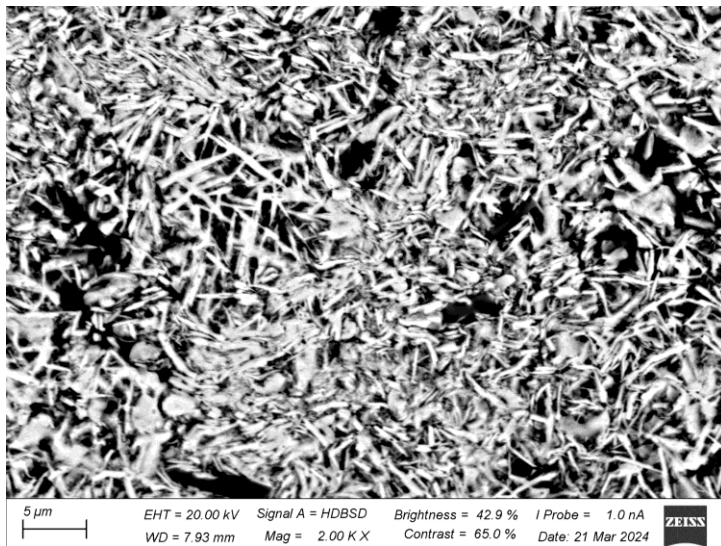
- Go forward with four small powder batches (6-7 weeks) and mix then together. C&H analysis will be on the mixed powder.



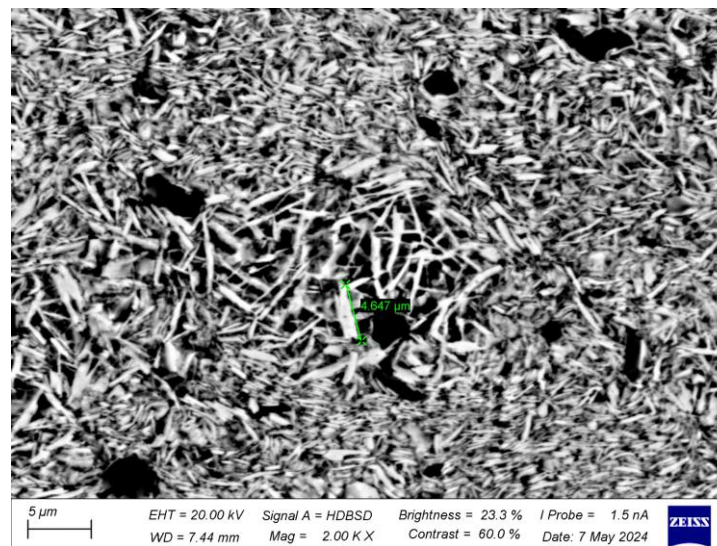
# [Task 2] Third billet – production and QA plan

- The first batch (G2A-15A\_HS) of the third powder had some AEC agglomerates under SEM (See Jianyi's presentation) (TS and CG agreed to quarantined this powder).
- The second (#3, G2A-18A\_HS) and third (#4, G2A-19A\_HS) batches of the third powder evaluated by Jianyi, 20A now looks good. 21A with Jianyi.

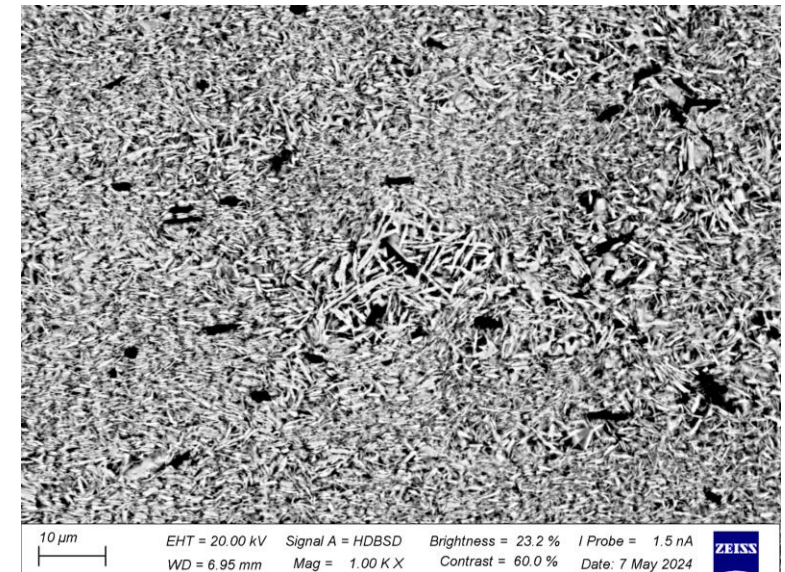
## G2A-15A\_HS



## G2A-18A\_HS



## G2A-19A\_HS

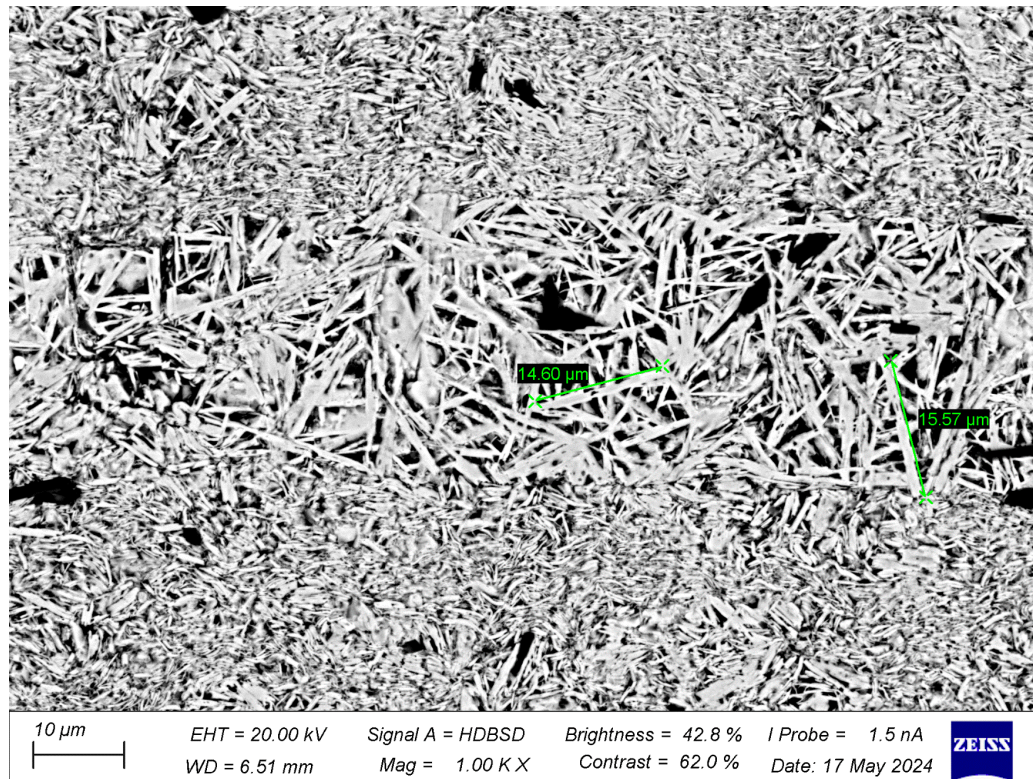


## [Task 2] Third billet – production and QA plan

- The second (#3, G2A-18A\_HS) is not in production as a 2 kg billet.
- Wire drawing to be completed in about 10 days.
  - 10 m @0.7 mm.

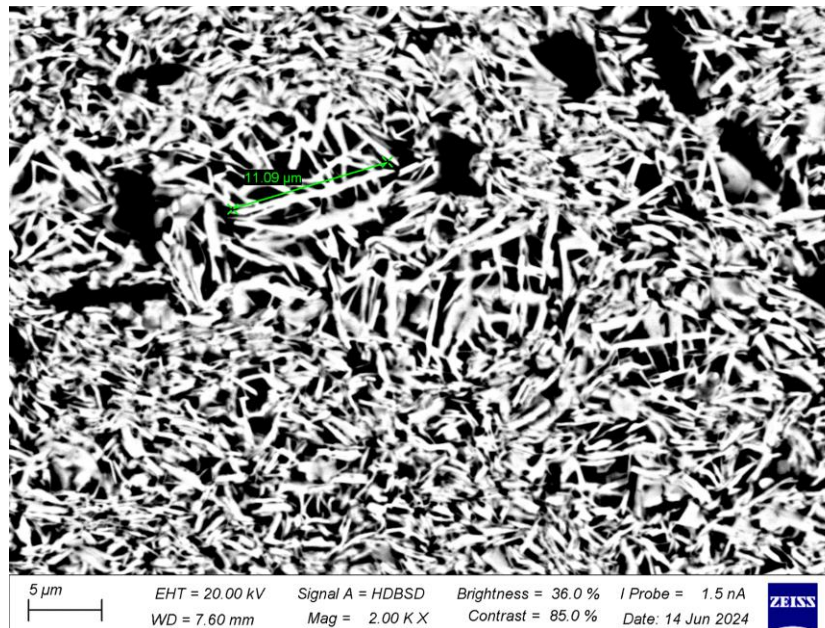
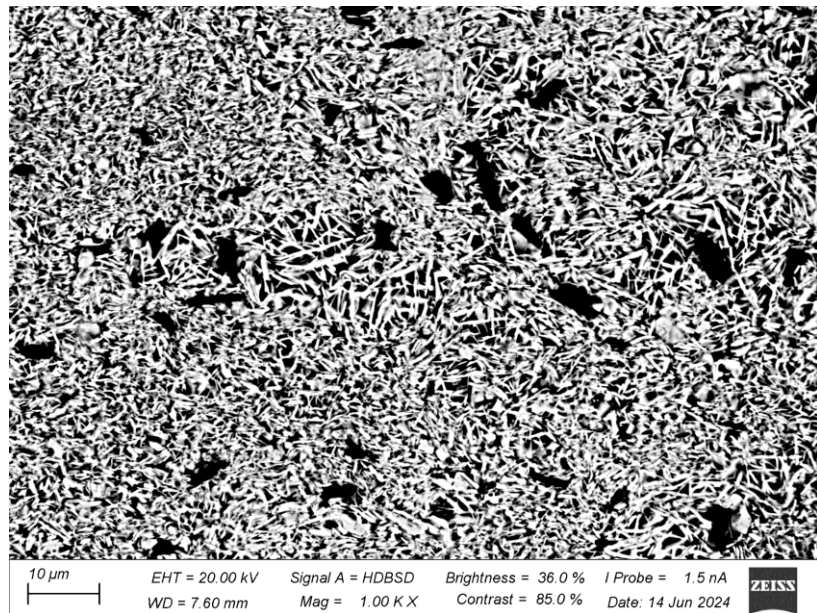


## G2A-20A\_HS



- No AEC agglomerate was observed in G2A-20A\_HS, but Bi-2212 grains of G2A-20A are larger than that of G2A-18 and G2A-19.

## G2A-21A\_HS



- No AEC agglomerate was observed in G2A-21A\_HS.

Jianyi,

Today, we shipped two Bi2212 powder samples to you for SEM. **Please note, both samples are for the DOE ARDAP project.**

- One sample is G2A-27A\_HS.

- The other sample is LXE-032. (500 g of this powder went to Bruker for fabrication of the third wire billet. You had previously collected SEM images of this powder (G2A-18A\_HS). The purpose here is to look at the powder again after the decarburization.)

The UPS tracking number is 1Z2335EW0391696213. The package is scheduled to arrive at your facility on Tuesday (7/9).

Best,

Dan



- [05/28/2024] Decision to move forward with a 2 kg billet production with (#3, G2A-18A\_HS).
- [05/30/2024] Powder has higher than expected carbon contents after decarbonization heat treatments. A second heat treatment has been applied.
- Powder characteristics will be examined after decarbonization heat treatment (s) as well.
- **[08/09/2024] Decision to move forward with a 2 kg billet (#4, G2A-19A\_HS).**
- A new powder batch was made G2A-35A\_HS **(Jianyi, SEM data 2024/10/07)**

# Billet #4

- **#4, G2A-19A\_HS**
- **Also modify the thermo-mechanical processing (remove intermediate annealing).**
- **The wire has been delivered to LBNL.**
  - **PMM240919-A, 0.8 mm, 124 m**
  - **PMM240919-B, 0.8 mm, 258 m.**
  - **Wire was delivered in two spools not because of wire breakage but because of a silver defect.**

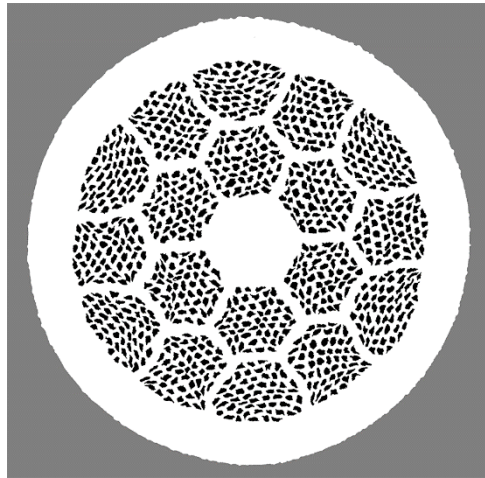
# Billet #5

- **[09/20/2024] Decision to move forward with a 2 kg billet (#5, G2A-27A\_HS).**

## ARDAP billet #5:

- G2A-27A\_HS – Engi-Mat will aim to deliver this powder to have a SSA as high as possible while meeting Bruker OST's Carbon & Hydrogen specifications (<100 ppm).
- Produced as 55 x 18.
- Bruker OST will attempt no annealing or a milder annealing at their discretion to increase filament uniformity and homogeneity along length.
- Bruker OST will do best to prevent water and air from entering into ends during the wire fabrication process.
- Engi-Mat will continue to produce powder and aim to have a higher SSA.

# A suggestion to look at effect of Ag-0.2wt%Mg sheath for future billets



Increase Ag-Mg-0.2wt% sheath, keep the wire diameter at 0.8 mm. Filament size drops and filament spacing reduced.

Increase Ag-Mg-0.2wt% sheath, increase the wire diameter accordingly To maintain filament size drops and filament spacing.

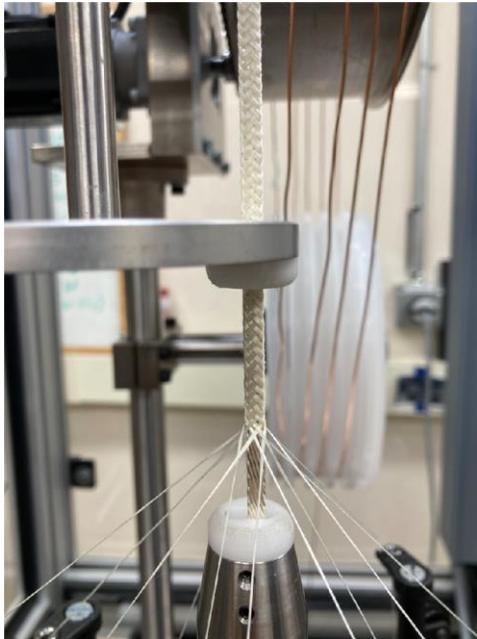


# Tasks

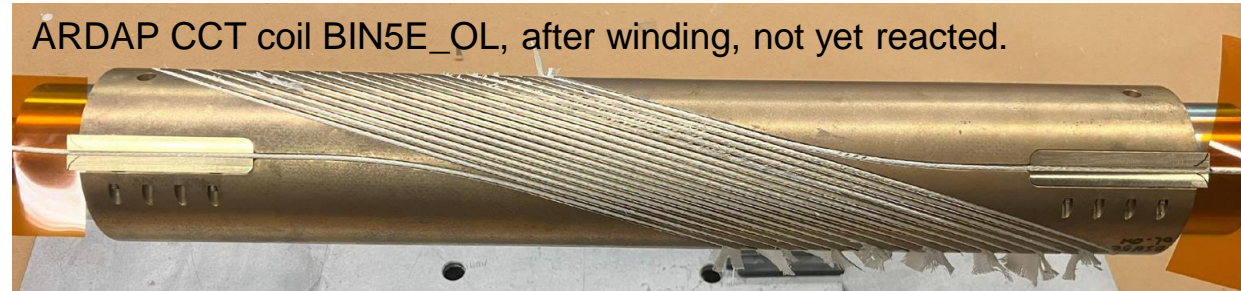
- **Task 0: Understanding the root cause of performance variation in existing Bi-2212 wires**
- **Task 1: Making precursor powder reproducible and improving production yield**
- **Task 2: Manufacturing 2 kg billets with reproducible plateau  $J_E(4.2 \text{ K and } 5 \text{ T}) > 1100 \text{ A/mm}^2$**
- **Task 3: Manufacturing 10 kg billets with the target  $J_E(4.2 \text{ K and } 5 \text{ T}) > 1100 \text{ A/mm}^2$**
- **Task 4: Powder and wire characterization**
- **Task 5: Understanding the science and technology of attaining high  $J_E$  in Bi-2212 Rutherford cables**
- **Task 6: Demonstrating predictability in Bi-2212 coil heat treatment**
- **Task 7: Insulation and leakage reduction for Rutherford cable coils**
- **Task 8: Contracts to procure powder as a strategic reserve**

# Task 7 – new insulation and removing leakage

- 7 m insulation braiding and coil winding trial completed.
- 24 m pure alumina insulated cable received.
- Winding of two coils completed.



By Youngjae Kim, FSU et al.



- CCT ARDAP coil BIN5E:
  - Outer layer coil wound. No electrical shorts.
  - Have to use  $\text{TiO}_2$  slurry to “repair, reinforce and lubricate” alumina fibers.
  - Possible to replace  $\text{TiO}_2$  slurry with  $\text{Al}_2\text{O}_3$  slurry (courtesy of Dr. Jun Lu, NHMFL)



- CCT ARDAP coil BIN5E:
  - Inner layer coil wound. No electrical shorts.
  - NEW: Use  $\text{Al}_2\text{O}_3$  slurry to “repair, reinforce and lubricate” alumina fibers. (courtesy of Dr. Jun Lu, NHMFL)

- BIN5E arrived at NHMFL on 05/17/2024.
- Heat treatment: 1) Organics burn off in Mellen. 2) OPHT (estimated in the end of June).

## Delivery Notification

<b>Ship From:</b>	LBNL, 1 CYCLOTRON ROAD, BERKELEY, CA, 94720, US
<b>Ship To:</b>	National High Magnetic Field Laboratory, 2031 E. Paul Dirac Dr., Tallahassee, FL, 32310, US
<b>Carrier:</b>	UPS
<b>Tracking:</b>	1Z9573570399569260
<b>Ship Date:</b>	05/13/2024
<b>Delivered Date:</b>	05/17/2024
<b>Signed By:</b>	

# First 2 kg billet (associated with Task 2/5/7)

- **37x18 wire, draw a short section to 0.8 and 0.7 mm, have a sufficient length for Jianyi to run characterizations (so we know  $J_E$  performance), then to 0.7 mm.**
- **The 0.7 mm strand will be made into a 6-strand Rutherford cable about 2.40 mm x 1.25-1.**

Table 2: A Rutherford cable to be fabricated for cable properties evaluation and as a potential solenoid conductor

No. strands	Nominal dimensions	Cable twist pitch (mm)	Strand diameter and design	Projected $I_c$ at 31 T (A)
6	2.4 mm x 1.25 mm	15 - 21.9	0.7 mm and 37 x 18	1150

- **Cable thickness can be decreased to 1.1 mm to increase the packing factor from ~78.5% to 88.5%, in light of the recent work by Jianyi.**
- **The coil plan discussion discussed.**

# Cable characterization and coil fab

- ITER barrels of cable 2007A/B/C. High field measurements. 15 T test first. Reaction barrel and test barrel fabrication to be completed, end of June.)
- ITER barrels of extracted strands? High field measurements. **2 samples each cable thickness. LBNL will prepare samples for reaction.**
- ITER barrels of round strands? High field measurements.
  
- Insulation schedule – pure Nextel. (Need a short piece for setting up fab. Include a Nb<sub>3</sub>Sn piece, 7 feet long).
- Cable fabricated and shipped to NHMFL.

Hi Andy,

Please cut 5 m cable 2007A (ARDAP billet #1) and keep it at LBNL.

Please cut 5 m cable 2008A (ARDAP billet #2) and keep it at LBNL.

Then send the following to Daniel Davis of the NHMFL.

- 12 ft long FRIB Nb<sub>3</sub>Sn cable piece (of same size) for insulation set up. (I have given it to you).
- 35 m strand PMM240325 for mechanical property study by Emma Martin, NHMFL. (I have it and will place it in the cabling room.)
- ~42 m cable 2007A (in this case, 5 m stayed at LBNL), ~7.5 m cable 2007B, and ~11 m cable 2007C.
- ~73 m cable 2008A (in this case, 5 m stayed at LBNL).
- Residual strands of cable 2007, #2-5.

**~150 m 6-strand cable  
(strand d = 0.7 mm)  
fabricated @LBNL**



**Insert solenoid  
for 31T @ NHMFL**

**High-field  
barrel test**



- **August 19 – potential magnet time.**

**Cable**

**High field coil**

# Meetings

- **Our next meeting: August 2, Friday okay?**
- **ARDAP PI meeting – August 1, 2024**



# Thank You