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Nanoparticle Ag-enhanced Textured-powder Bi-2212/Ag Wire Technology

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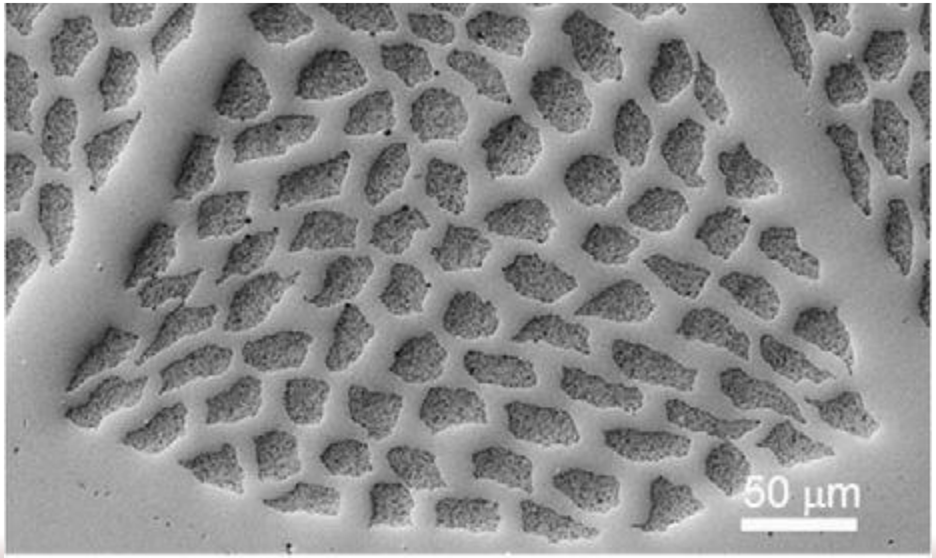
Outline

- Motivation / Background
  - 2212 motivation
  - Textured Powder (TP) cores
  - Enhanced Textured Powder (ETP)
- Procedure
  - Powder handling
  - Die and pressing
  - ETP core preparation
- Pellet studies
  - Heat treatment test
  - Resistance test
- Conclusion / Future work

Development of Bi-2212 Round Wire

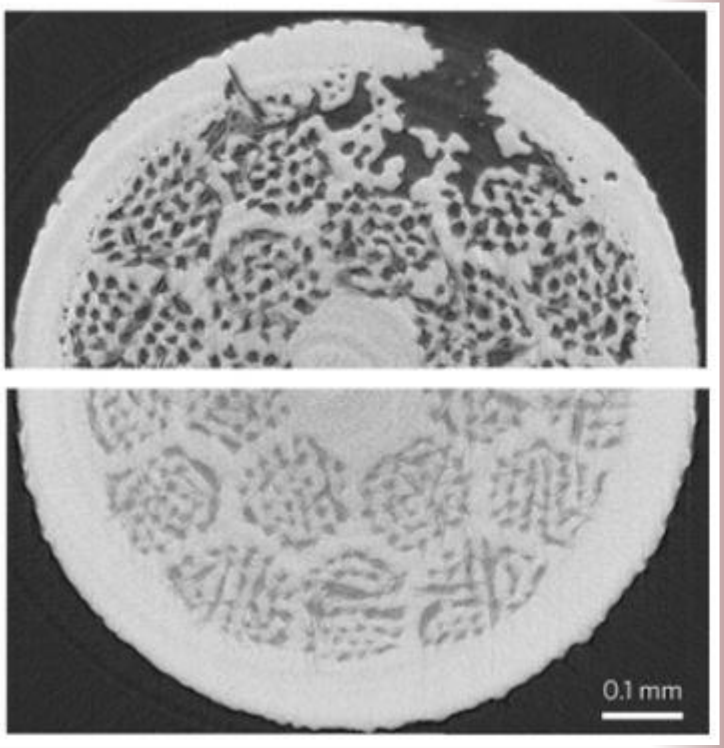
- State of the art fabrication of Bi-2212 is oxide powder in tube (OPIT)
  - Fine powder Bi-2212 is loaded into silver or silver alloy tubes
  - The tubes are drawn, stacked, and re-drawn to make multi-filament wire
  - The wires are cabled and wound into their final form
  - The windings go through a partial melt process during which the Bi-2212 solid particles are melted and re-crystalized



Kametani *et al*, Supercond. Sci. Technol. 24 (2011) 75009

Development of Bi-2212 Roundwire

- Some problems arise from this partial melt heat treatment
  - Void spaces between Bi-2212 particles become bubbles when the powder is fully melted
  - The bubbles combine and form large voids in the wire that can block current transport
  - The liquid will etch along grain boundaries of the silver matrix
  - Overpressure processing at 5~10 Mpa during heat treatment has dramatically improved current transport performance



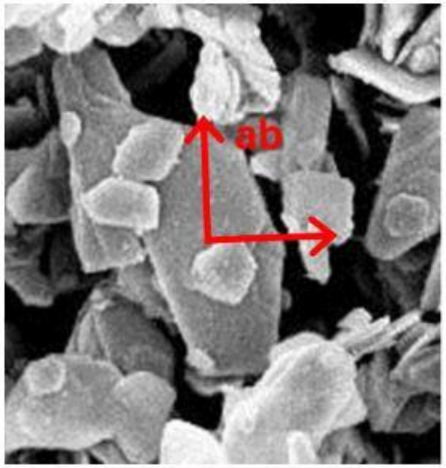
Larbalestier *et al*, Nature Materials. 13, 375-381 (2014)

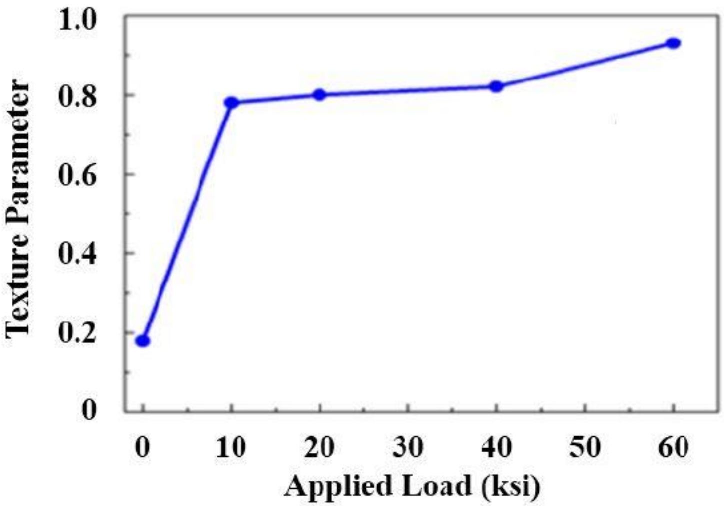
Motivation

- We set out to develop a new method of fabricating Bi-2212 round wires that avoids some of the problems of the PM process.
  - Texturize the powder before heat treatment.
  - Stay below melt temperature as not to fully liquefy the Bi-2212 and avoid the coalescence of void spaces and maintain texture.
  - Produce excellent grain growth and interconnectivity after heat treatment
  - Minimize presence of parasitic phases, AECs, and CuF regions

Textured Powder (TP) Cores

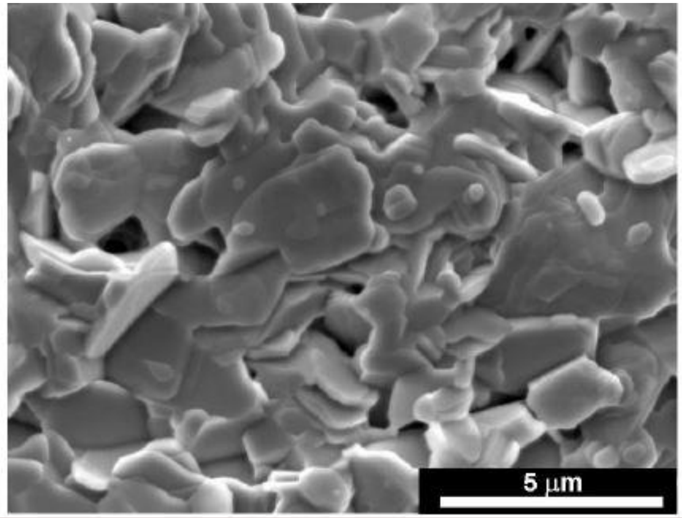
- Bi-2212 powder of ~1μm is uniaxially pressed at 20 KSI into square cross section bars (4mm x 4mm x 150mm)
- This aligns the orientation along the a-b plane of the micaceous powder
- The motivation was to achieve connectivity between textured grains through a heat treatment that stays below melt temperature.
- The transition to liquid is never made and the favorable texture is maintained

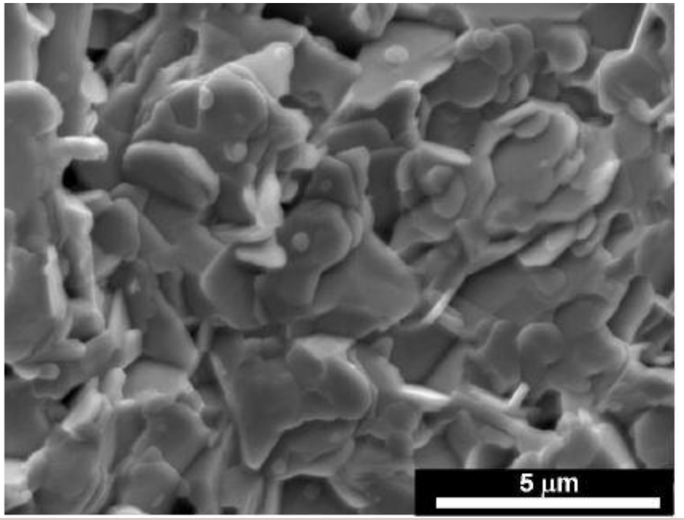




Textured Powder (TP) Cores

- Silver sheathed TP cores were drawn to fine wire.
  - Wire drew well with no sausaging or breaks
  - A heat treatment development was done to find a domain that produced Bi-2212 grain growth and connectivity.
  - Grain growth was observed and texture was maintained, but interconnectivity was not achieved.
  - Transport measurements were made but no significant transport was found.





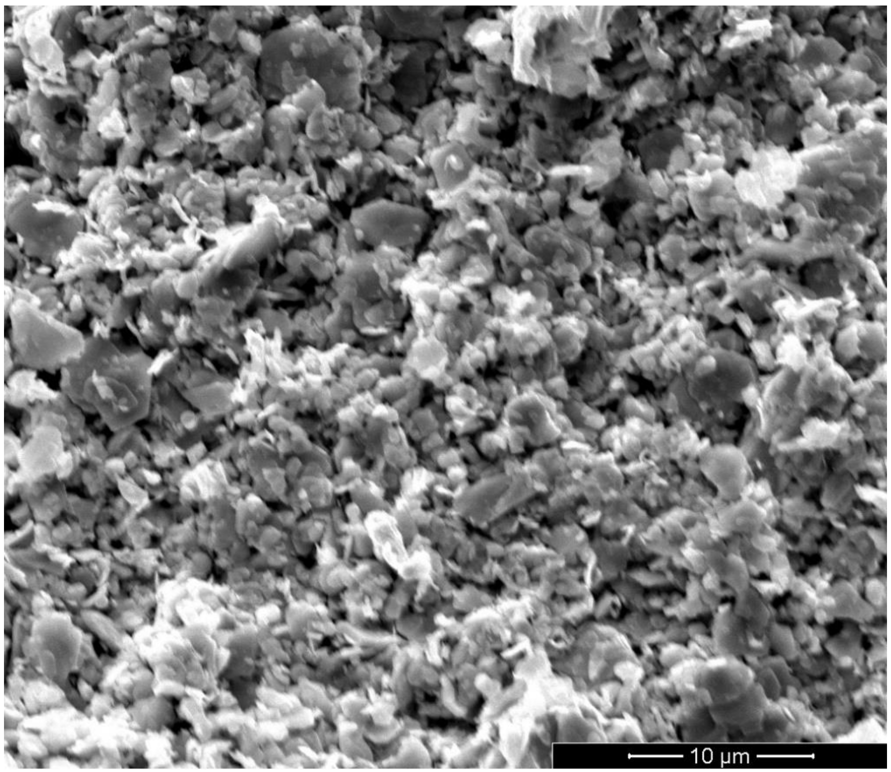
Enhanced Textured Powder (ETP)

- It is known that the properties of Bi-2212 is strongly affected at a silver interface. The melt temperature is lowered and the majority of current flows near this interface in OPIT wire
  - Our goal is to create this interface not just at the sheath but everywhere in the Bi-2212 core
  - Silver nanopowder of two sizes 20 nm and 100 nm is added to the Bi-2212 powder

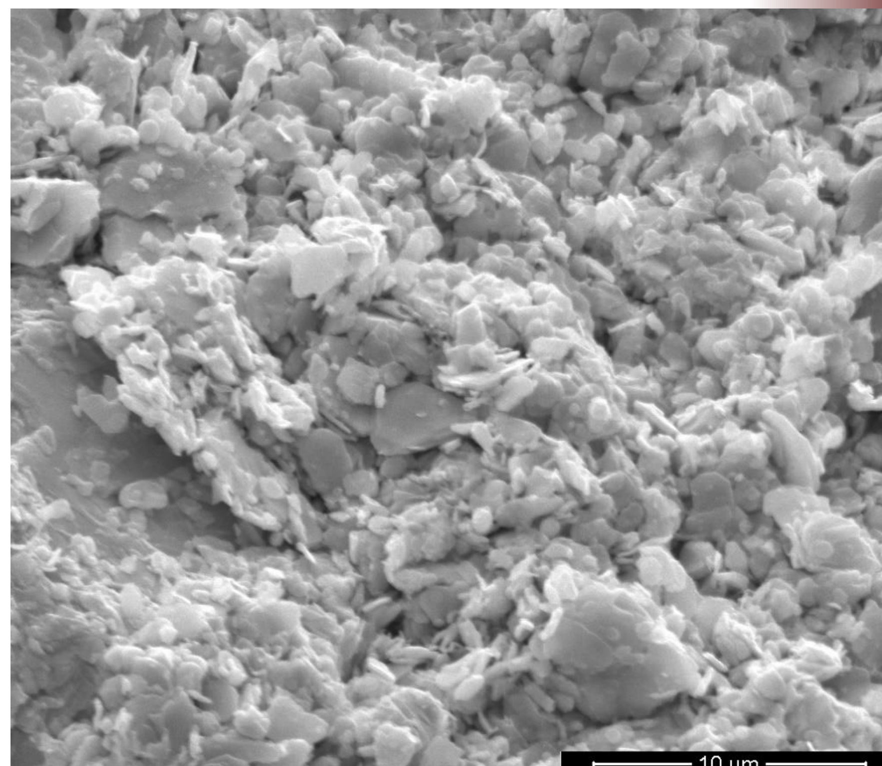
Mixture	Ag / Weight %	Ag particle size
Large 3%	3%	80-100 nm
Large 5%	5%	80-100 nm
Small 3%	3%	20 nm
Small 5%	5%	20 nm

Powder Handling

- The silver nanopowders are mixed homogenously with the Bi-2212 using acoustic mixing
- Pellets were pressed and the green-state microstructure was analyzed to confirm a homogenous mixture.



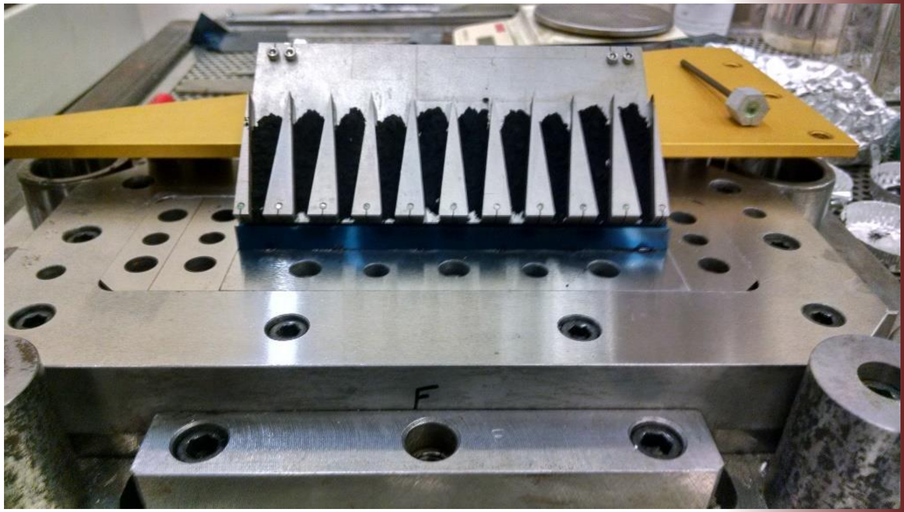
5% silver by weight 20 nm



5% silver by weight 100 nm

Pressing procedure

- Due to the lack of "flow" of the powder it is important to have the powder uniform in the slot.
  - A powder slide is used with measured amounts of powder going along each groove to fill the die slot uniformly.
- The die is placed into the press, and a tent is placed around it with inert gas flowing during the entire pressing procedure to limit the cores exposure to air.



ETP Cores

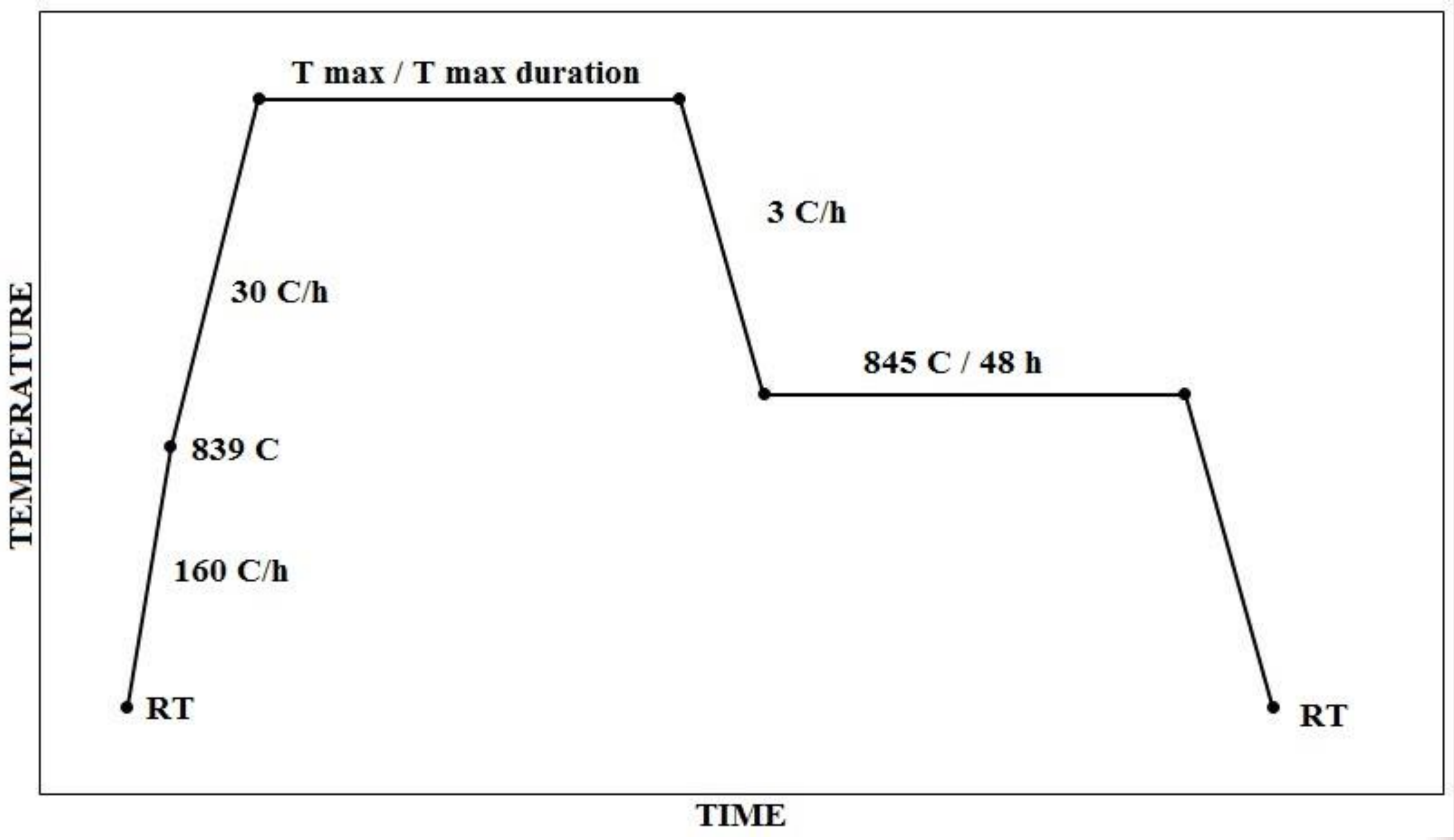
- The ETP cores that were pressed were curved when removed from the die.
  - These ETP cores need to be inserted into a silver alloy sheath and therefore must be straight
  - Pressing a ceramic powder with high pressure in a die can cause a density differential between the top and the bottom of the product when a single action die is used.
  - A double action die is optimal, but would be very difficult to start with a powder for a floating die assembly.
  - A curved die was precision cut so that the ETP cores were straight when removed from the die

ETP Cores

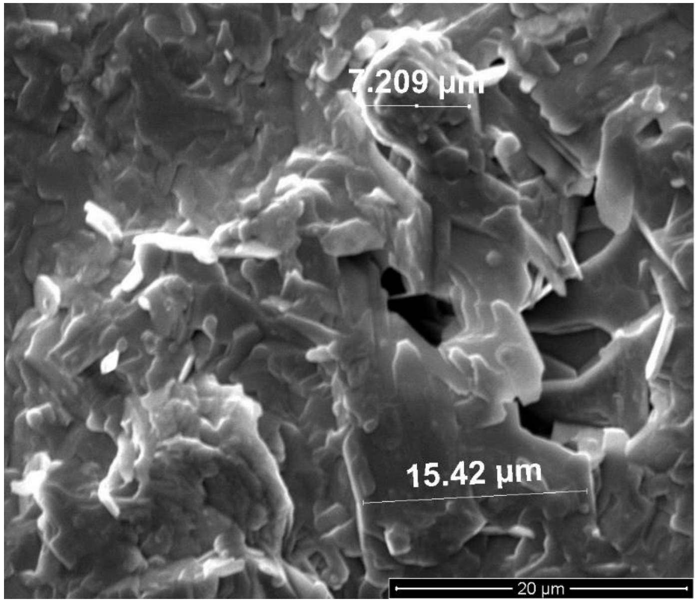
- The silver tube that the ETP cores are inserted into is not quite square.
  - The ETP cores must be filed slightly to fit, but the cores are extremely fragile and do not respond well bending, twisting, or vibration.
  - A fixture was made to allow the cores to be filed, and inserted into the silver with minimal handling.

Heat Treatment Tests

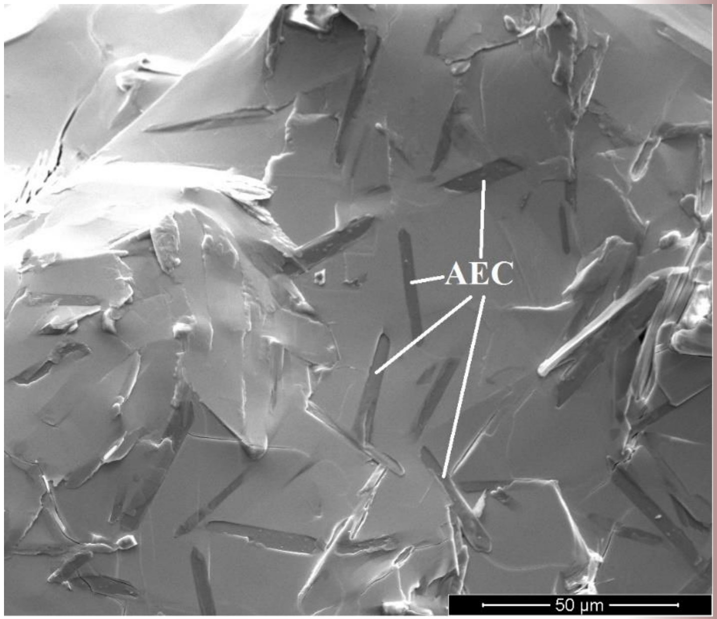
- Pellets of the ETP were pressed to test various heat treatments parameters



Heat Treatment Tests

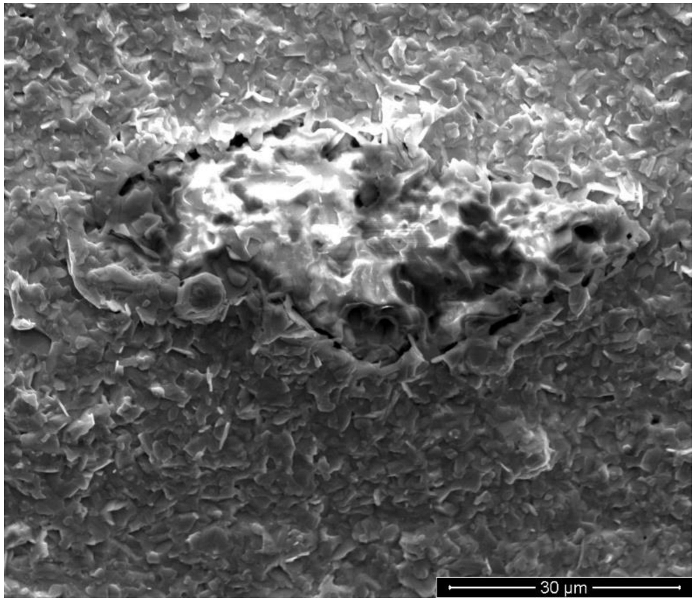


This sample was heat treated with a maximum temperature of 878 C for 48 hours and annealed. Excellent grain growth and interconnectivity was achieved. No parasitic phases, AEC, or CuF regions were present

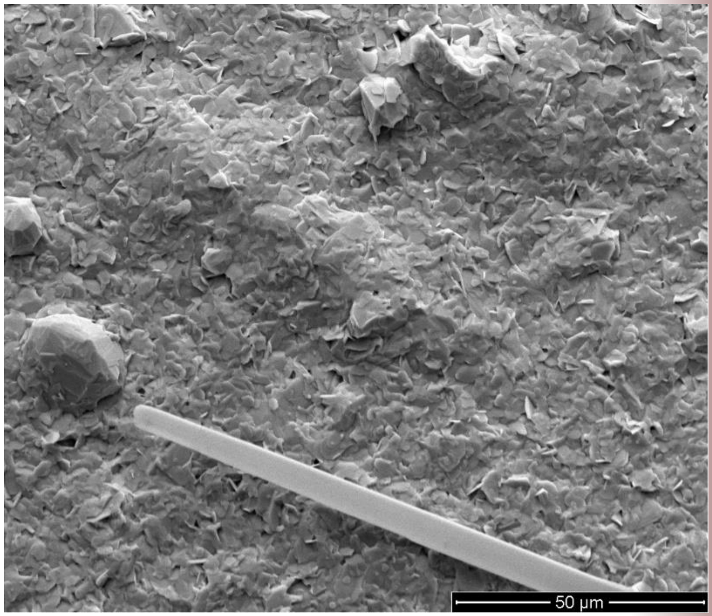


This sample was heat treated with a maximum temperature of 881 C for 0.5 hours and was not annealed. AECs and CuF regions become very common

Heat Treatment Tests

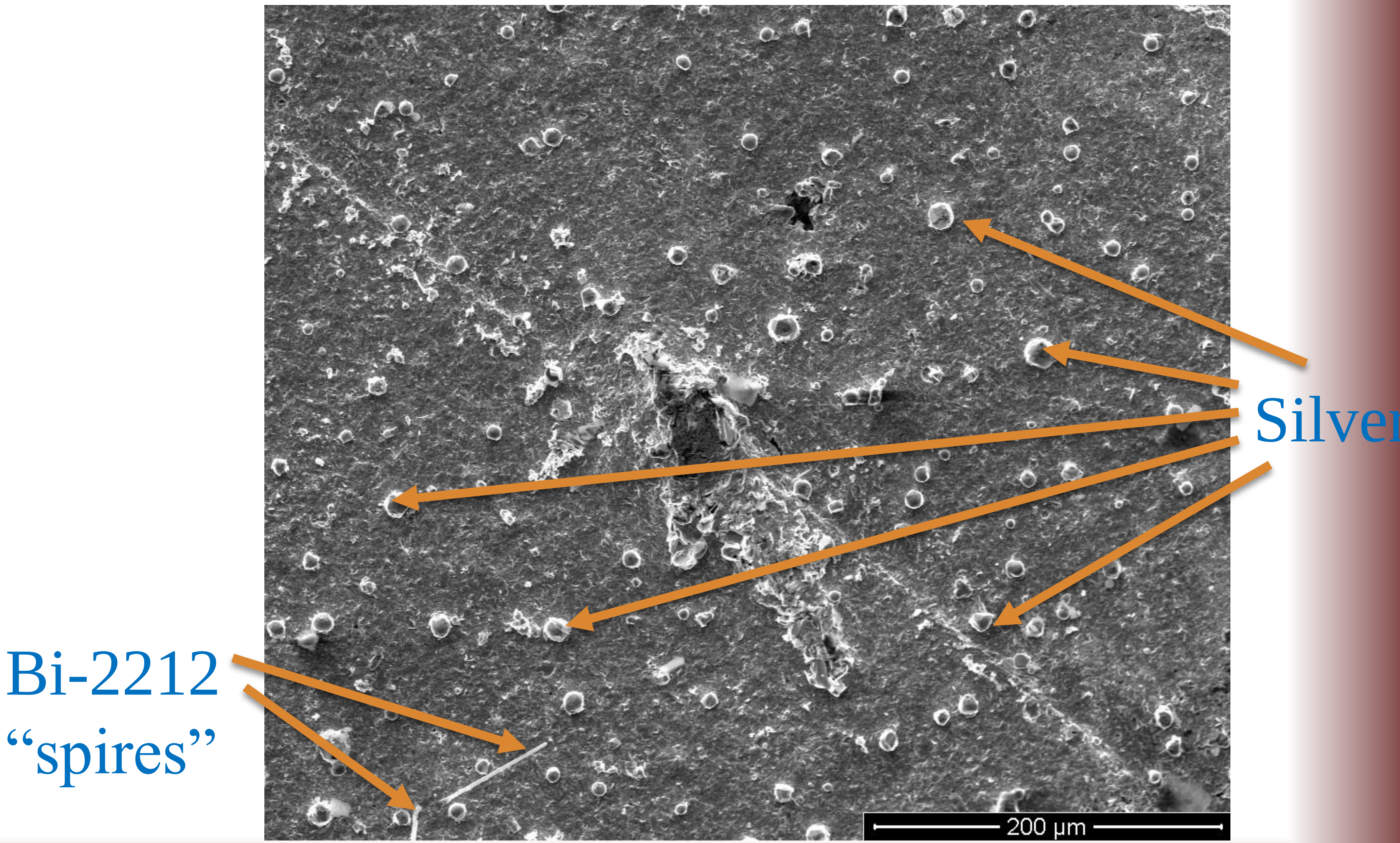


This sample was heat treated with a maximum temperature of 876 C for 6 hours and was not annealed. Large parasitic phases were common, but no AECs or CuF regions were present.



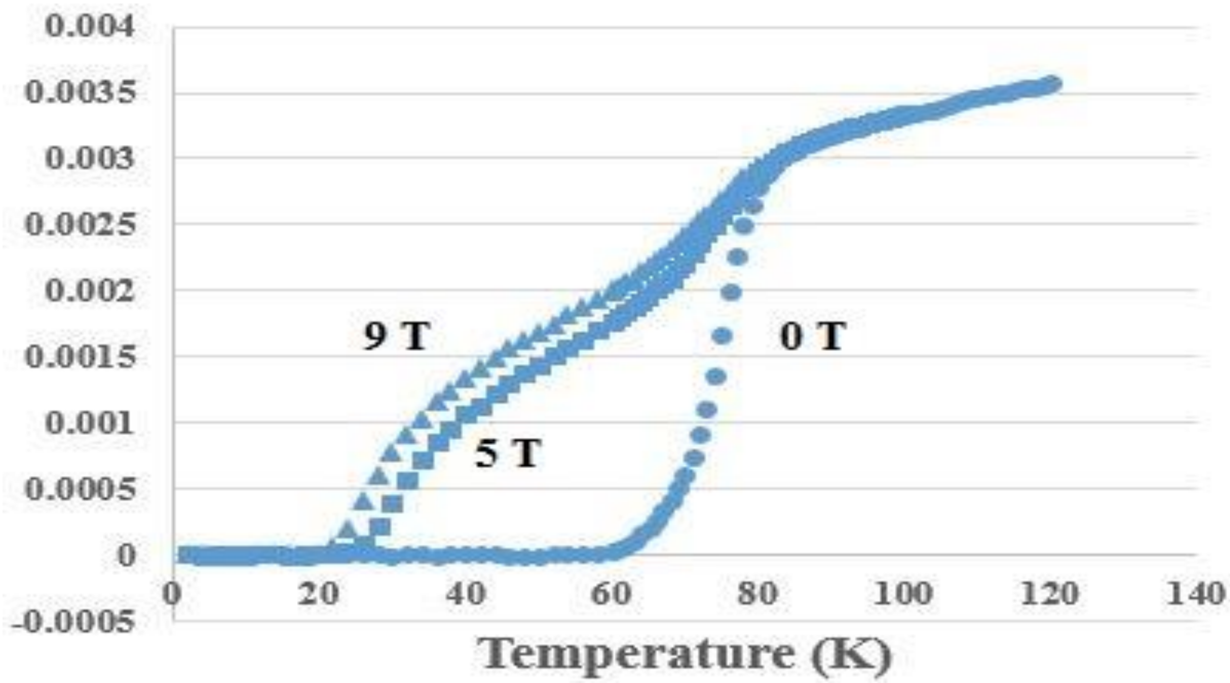
This sample was heat treated with a maximum temperature of 876 C for 6 hours and was annealed. No parasitic phases, AECs or CuF regions were present.

Silver Spheres



Resistance Test

- A four point silver tab configuration was pressed in a green-state ETP pellet.
- The pellet was heat treated to a maximum temperature of 878 C without annealing (parasitic phases present).
- Macroscopic supercurrent was achieved over ~1 cm



Conclusion

- Excellent grain growth has been achieved
- Interconnectivity between grains is observed in SEM images
- Supercurrent achieved on a macroscopic scale

Future plans

- Wire will be drawn out of 4 different ETP cores in one tube
- Wire will be wound on ceramic barrels
- Various heat treatments will be tested based off of pellet studies
- Windings will be tested for supercurrent transport

Acknowledgements

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- Nexans
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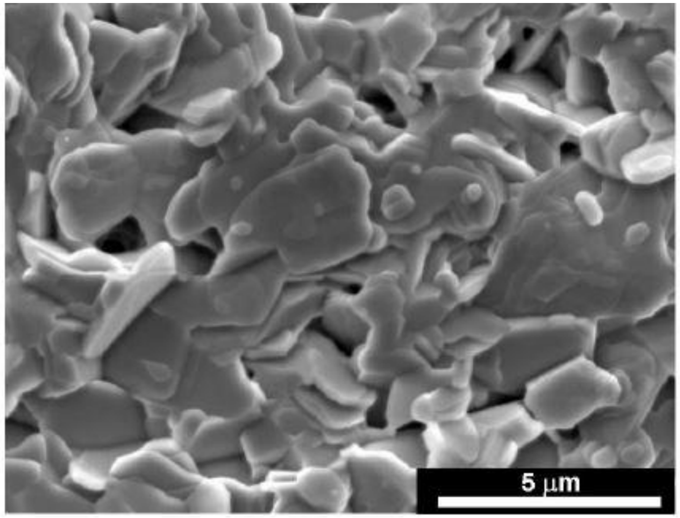
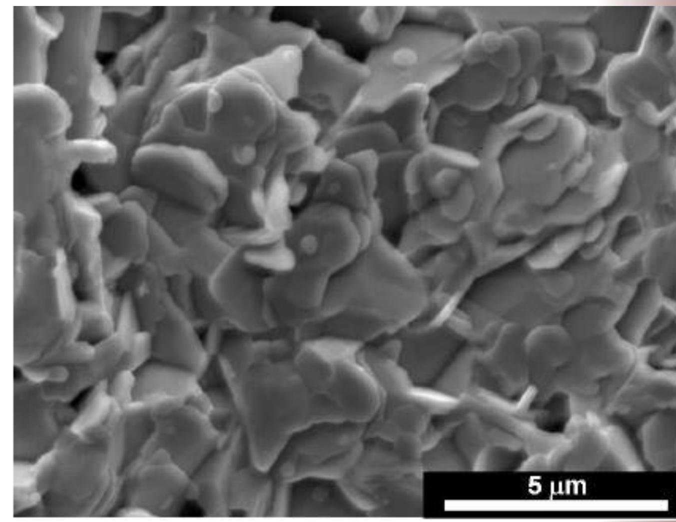
TP compared to ETP

TP





ETP