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

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

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

<table>
<thead>
<tr>
<th>Mixture</th>
<th>Ag / Weight %</th>
<th>Ag particle size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large 3%</td>
<td>3%</td>
<td>80-100 nm</td>
</tr>
<tr>
<td>Large 5%</td>
<td>5%</td>
<td>80-100 nm</td>
</tr>
<tr>
<td>Small 3%</td>
<td>3%</td>
<td>20 nm</td>
</tr>
<tr>
<td>Small 5%</td>
<td>5%</td>
<td>20 nm</td>
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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 to 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

![Diagram of heat treatment parameters](image)
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

Bi-2212
"spires"

Silver
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

Thank you!

• K. Damborsky
• R. Garrison
• L. Motowidlo
• John Buttles & Bailey tool
• Nexans
• John Neraas, Resodyn

Graduate Students
• Karie Melconian

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TP compared to ETP

TP

ETP