Characterization of Mechanical Properties of $Bi_2Sr_2CaCu_2O_{8-x}$ Superconductor through Scanning Electron Microscopy

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Background

What are we studying?

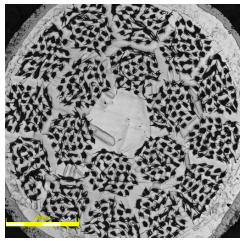
- **$Bi_2Sr_2Ca_1Cu_2O_x$ (Bi-2212)** - a high temperature superconductor

Why are we studying it?

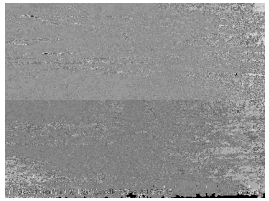
- Superconductors are used in a wide variety of high field magnetic applications.
- Bi-2212 is the only high temperature superconductor available as a round wire that is suitable for magnets.

What are we looking for?

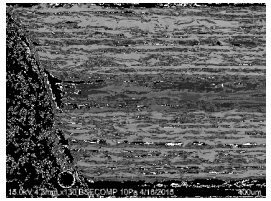
- Bi-2212 is brittle and susceptible to mechanical damage.
- Our research seeks to understand why this damage occurs, and how it propagates through the material.



Laser confocal image of transverse mounted Bi-2212 wire



SEM image of a longitudinal mounted Bi-2212 wire



SEM image of a deep etched longitudinal Bi-2212 wire

High magnification SEM image of Bi-2212 filaments

Electro-mechanical Testing

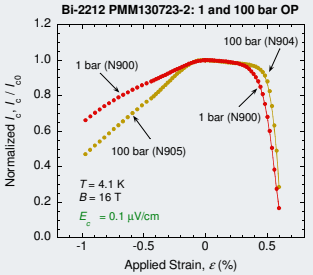
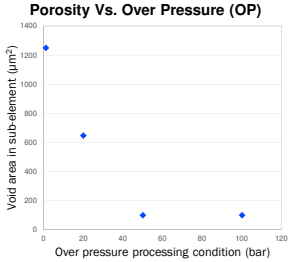


Image courtesy N. Cheggour, University of Colorado-Boulder. Data collected under UWEC sub-contract.

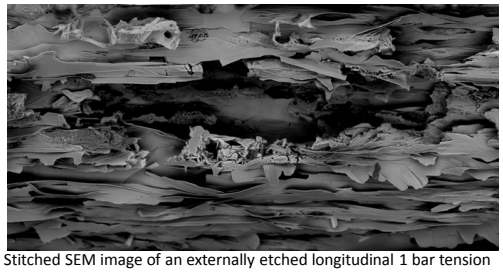
Electromechanical data showing the effects of heat treatment overpressure on samples tested in tension and compression.



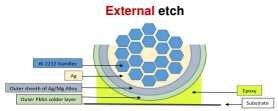
The amount of porosity present in polished cross-sections of 1 bar, 20 bar, 50 bar, and 100 bar heat treatment samples. **1 bar wires more readily resist catastrophic damage in compression.** Cracks are arrested by the high porosity concentrations.

Characteristic Failure Mechanisms in Different Strain Modes

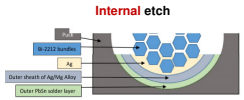
Tension strain behavior



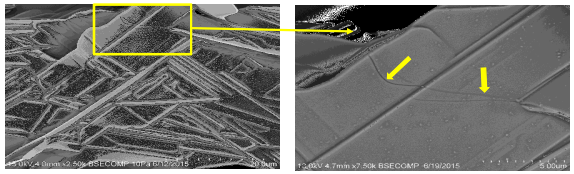
Stitched SEM image of an externally etched longitudinal 1 bar tension Bi-2212 wire with missing outer ring filament due to **mechanical testing damage**



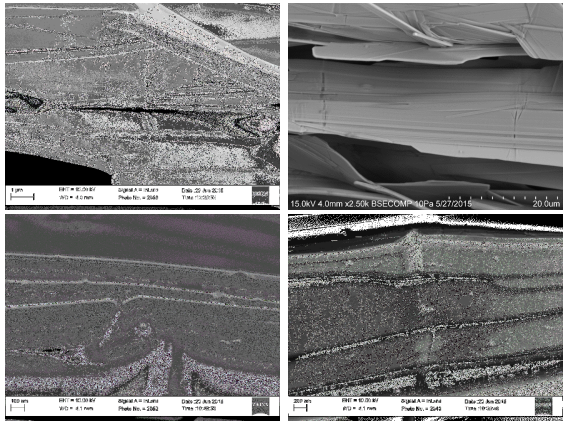
Above: used to evaluate outer ring of filaments without local polishing on a 1 bar tension Bi-2212 wire



Below: used to evaluate inner ring of filaments without local polishing on a 100 bar tension Bi-2212 wire

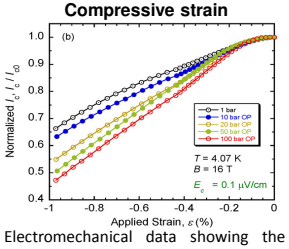


100 bar Compressive strain behavior



FESEM images of an internally etched longitudinal 100 bar compression Bi-2212 wire show both outward and inward buckling events. due to **mechanical testing damage**

Compressive strain



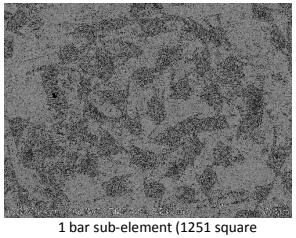
Electromechanical data showing the effects of different heat treatment overpressures on samples tested in compression.

Conclusion

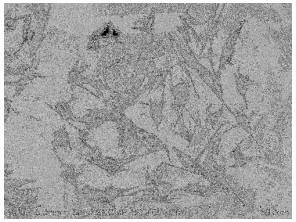
Tension samples exhibit very little damage on the internal ring of sub-elements, instead failing mechanically along the outer ring of sub-elements—as found by employing unique sample preparation techniques, such as external etching. Current data suggests high density of 100 bar filaments translates into better mechanical strength in the tensile regime.

Conclusion

Compression samples preferentially crack perpendicular to the growth direction of Bi-2212 grains. **100 bar wires exhibit extensive electromechanical degradation due to a lack of crack arresting mechanisms.** Due to the high density of 100 bar Bi-2212, compressive stresses lead to buckling in the filaments.



1 bar sub-element (1251 square microns of void space)



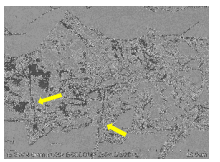
100 bar sub-element (100 square microns of void space)

Effect of Large Powder Particles

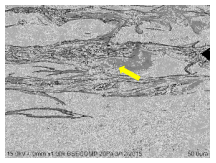
SEM images after attack polish, tested under compression: a) in **1 bar** heat treated wire, the cracks are **largely arrested** by the **high porosity concentrations**

After the partial melt, large grains from the superconducting powder remain as large areas, or "clunkers", in the microstructure. Grain interfaces, particularly with large differences in orientation, impede current flow.

b) in **100 bar**, more packed Bi-2212 sheets, denser filaments, the crack can **propagate** easier to larger sizes, including the large, hard particles.



1 bar



100 bar

Acknowledgements

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