The Impact of Powder Source on the Processing Uniformity of Green-Treated $Bi_2Sr_2CaCu_2O_{8-x}$ (Bi-2212) Superconducting Wire Using Digital Image Analysis

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Introduction

❖What are we studying?

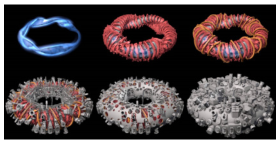
❖ **$Bi_2Sr_2Ca_1Cu_2O_{8-x}$ (Bi-2212):** is a high temperature superconducting round wire material that is able to produce magnetic fields greater than 25 T.

❖What's the goal of this research?

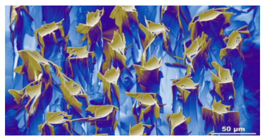
❖ This research seeks to investigate how the powder source impacts the uniformity of filament size and shape within the silver matrix of the wire.

❖ This can be used by the manufacturers to help improve the drawing properties of the wire.

❖ Wires like this can be fabricated into powerful magnets used in particle accelerators, fusion devices, and MRIs



Germany's Wendelstein 7-X Fusion reactor
https://i.imgur.com/eikBLMX.jpg



Individual Bi-2212 filaments after heat treatment, in an etched Ag matrix. Image courtesy Dr. Peter Lee, FSU.

Bi-2212 Wire

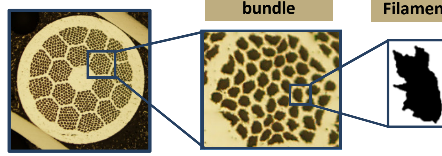
❖ The Bruker-OST Bi-2212 wire is composed of a silver matrix with Bi-2212 powder-filled filaments

❖ The wire is composed of 18 sub bundles with three geometries, each consisting of 55 filaments.

❖ We were provided 0.8 mm diameter green wire samples, a front end (FE) and back end (BE) of each wire.

❖ The wire samples contained powder from two different manufacturers, labeled on this poster as powder A and powder B.

Bi-2212 Wire | Hexagonal Sub-bundle | Individual Filament



Procedure

❖ To be able to take a transverse cross section image, the wire is first mounted in a conductive epoxy and then polished

❖ Once the wire is free of scratches we use an attack polish method to help etch back some of the silver to make the bundles more prominent

❖ With the SEM we take 550x magnification photos of the wire and we can stitch those together in Photoshop

❖ From the stitched image we use FIJI to make a clear image threshold to analyze

Stitched Image | Threshold | Threshold check

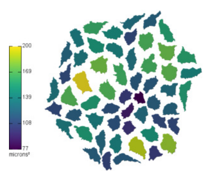
Image Analysis Parameters

❖ The parameters that were chosen to be analyzed were; the **area**, **circularity** and **nearest edge distance** of each filament

❖ To do image analysis on the wire the software program ImageJ was used

Area

❖ Using a FIJI routine, a color-coded map of the area of each individual filament in each bundle is generated.



Nearest Edge Distance

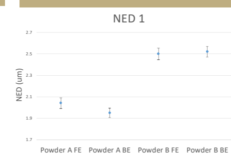
❖ A distance matrix of the proximity of each neighboring filament is generated and the nearest edge distance (NED) is determined.

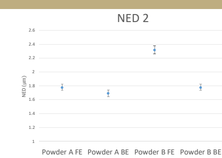
Circularity

❖The circularity of each filament (see examples at right) is calculated using a FIJI routine.

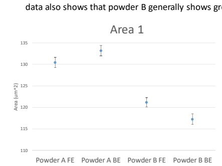
Circularity =.367 Circularity =.525 Circularity = .633

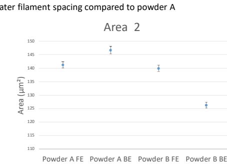
Trial One / Trial Two



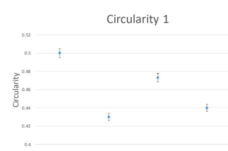


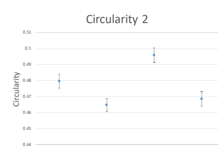
❖ Here it's shown that wire filament spacing grows more compact from the front end to the backend. The data also shows that powder B generally shows greater filament spacing compared to powder A





❖ This set of data shows that the powder choice has a significant impact on the area of the filaments. Powder A shows much higher area values when compared to powder B





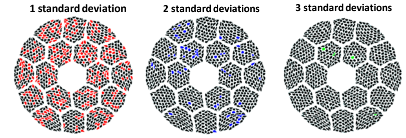
❖ This circularity data shows that with the circularity of the filaments decrease as you go from the front end to the back end of each wire. This shows that there may be an issue with manufacturing uniformity

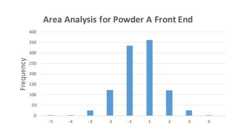
Results

Trial One	Powder A FE	Powder A BE	Powder B FE	Powder B BE
Average Area (µm²)	130	133	121	117
Average NED (µm)	2.04	1.95	2.50	2.52
Average Circularity	0.500	0.430	0.473	0.440

Trial Two	Powder A FE	Powder A BE	Powder B FE	Powder B BE
Average Area (µm²)	141	147	140	126
Average NED (µm)	1.78	1.69	2.32	1.78
Average Circularity	0.480	0.465	0.496	0.469

Standard Deviation Analysis Results (Powder A Front End Trail One)





❖ For most samples analyzed, the distribution of filament sizes closely follows that expected by a normal distribution, including the number of outliers beyond +/- 3 standard deviations.

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Conclusion

❖ The powder source has a **statistically-significant impact on the overall filament size and spacing shown in the graphs.**

❖ The drawing process produces **slightly more circular filaments** near the front end of the billet for both powder manufacturers as well as larger more compact filaments for powder A

❖ The shape of the sub-bundle **does not impact the filament geometry** (area, circularity, etc.)

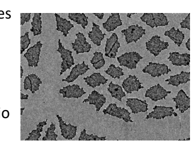
❖ Similar trends were shown for each wire which should be expected. However there are some differences between the two trials. This is the result of differing techniques during sample prep and image analysis. Further work is needed to standardize the procedure.

What's Next?

❖ This research seeks to further the investigation of these wires by analyzing filament roughness and fill factor of each wire

❖ New SEM acquisition settings were found that gave the desired amount of detail in the filaments for roughness analysis

❖ In image analysis, perimeter roughness is defined as the ratio of the convex perimeter to the actual perimeter



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