Density measurements of Bi-2212 filaments – towards high-field magnet applications

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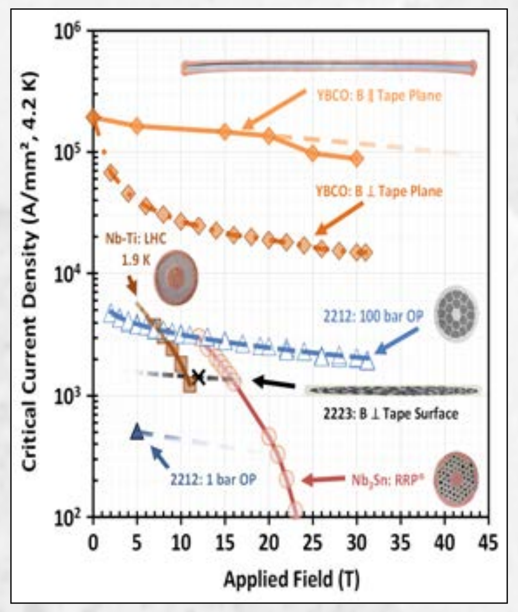
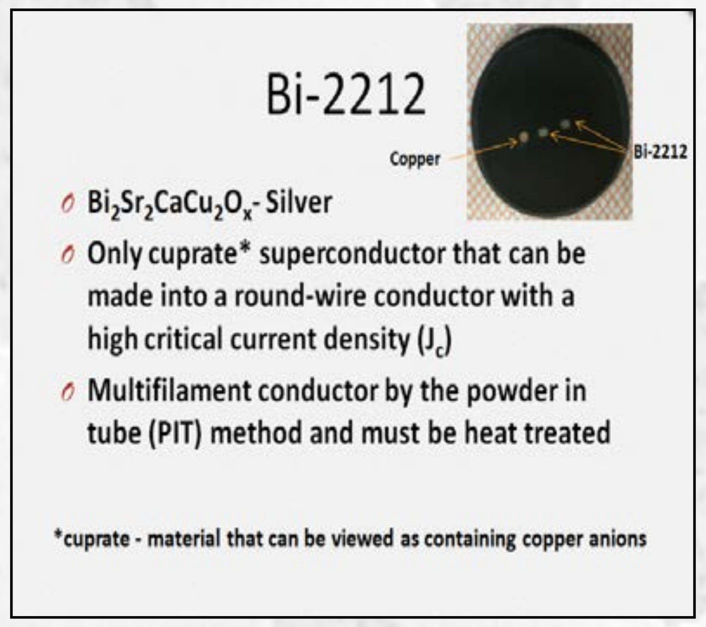
INTRODUCTION

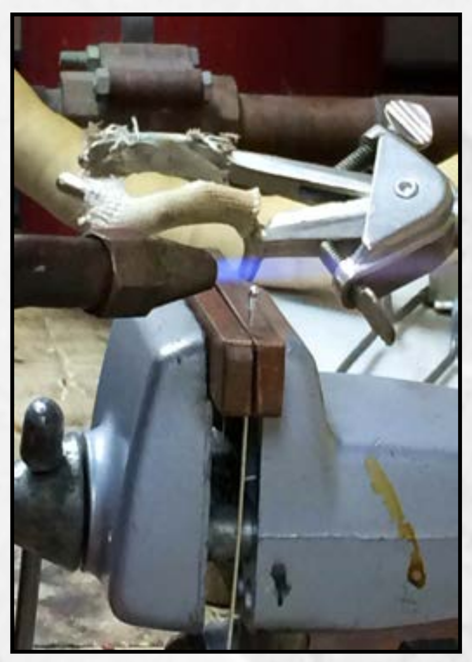
Superconductivity is a promising and exciting field of physics. Superconductivity is the flow of electricity without resistance in certain metals, alloys, and ceramics. This means they can conduct electricity without loss of energy. This phenomenon occurs when the temperature is below a critical temperature. These characteristics make them well suited for building extremely strong electromagnets. Present day research involves experimenting with conductors which will allow for the flow of greater currents through smaller wires. Superconductivity has practical application in emerging fields in medicine, electronics, industry, power generation and transportation.

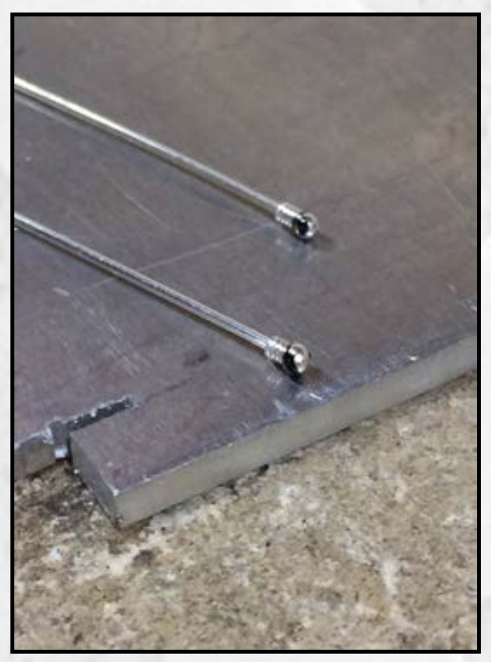


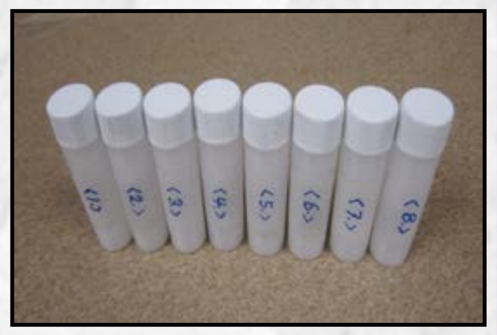


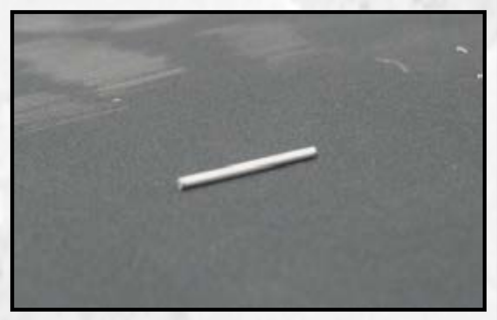
MATERIALS

Round wire conductor made of the high temperature superconductor *$Bi_2Sr_2CaCu_2Ox$ (Bi-2212)*. Bismuth Strontium Calcium Copper Oxide is a ceramic superconductor. The silver encased Bi-2212 filaments compose the round wire which is fabricated as a multifilament conductor by the powder-in-tube (PIT) method, but it must be heat treated at final size by partial melting to develop a high critical current density. This wire is useful in strong electromagnets.









PURPOSE

A remarkable attribute of this Bi-2212 conductor is that it does not exhibit macroscopic texture and contains many high-angle grain boundaries yet attains very high superconducting critical current densities (J_c) of 2500 A/mm² at 20 T and 4.2 K. Comparing densities of round and rectangular wires before and after heat treating provides valuable data about the superconductor's ability to achieve higher critical current densities. Bi-2212 densities >70% are preferable. Comparing the densities of wire densified in production and densification through overpressure after manufacture was done.

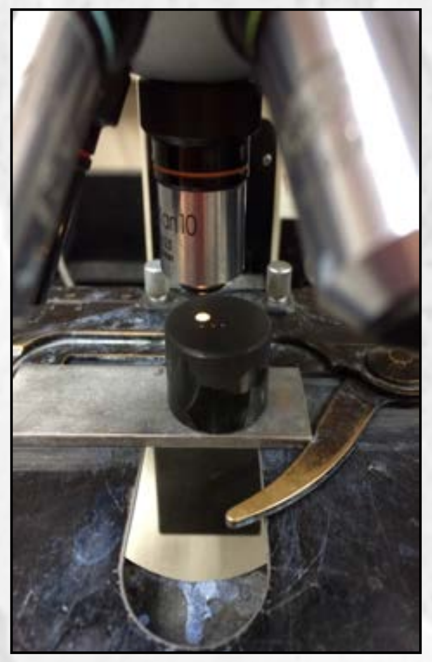
PROCEDURE

To study the microstructure, wire samples are placed in round, conductive polymer pucks. The puck is then sanded and polished using silicon carbide sand papers which creates a smooth, scratch-free surface. The puck is then placed in a Vibro Met machine for approximately three hours for the final polishing. High quality polishing creates well defined pictures for analysis. Images were obtained using an Olympus BX41M-LED Microscope. Images are taken using Stream Motion and Photoshop software. The images are then stitched together and a black and white image is created for pixel analysis. The pixel data is used to calculate the density of the Bi-2212 within the wire.

Weighing KonductoMet to make a polymer puck

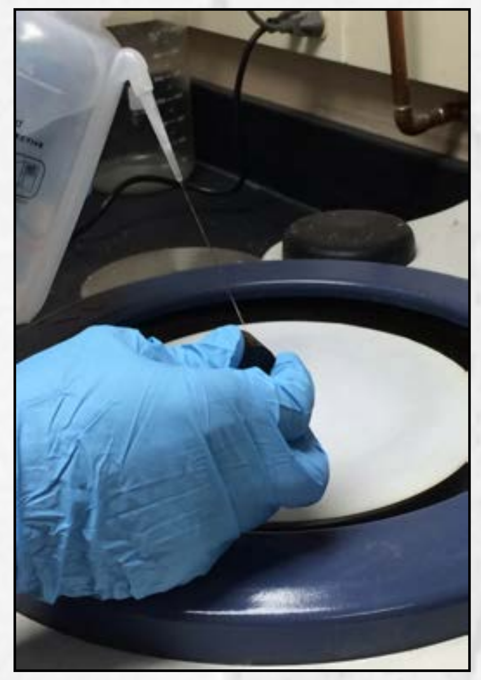
Making a polymer puck with a Simplimet 3000 mounting press

Preparing Bi-2212 wire samples for initial measurement



Checking a Bi-2212 sample for scratches and imperfections

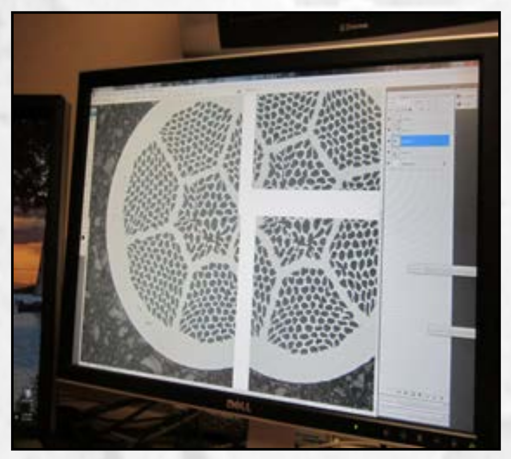
Dry polishing a puck with 400-800 grit silicon carbide paper



Finishing polish with Ethanol and nylon pad

Final polish using the Vibro Met 2

Polished sample ready for image capture and analysis



Stitching sample wire photos

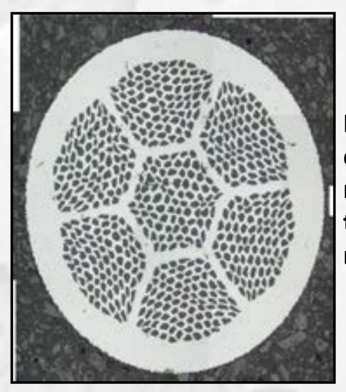
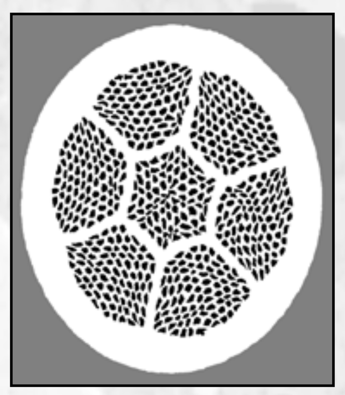


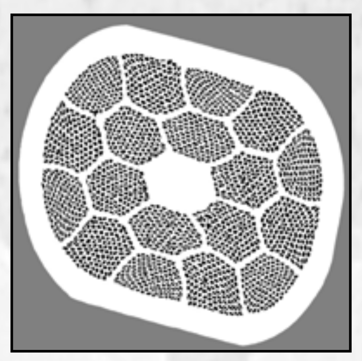
Image of 1.0 mm diameter green round wire using the Olympus microscope at 20x



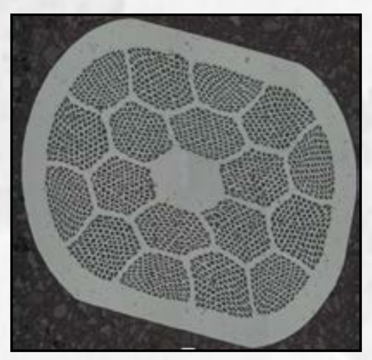
Black & White image of 1.0 mm heat treated round wire using Photoshop

ANALYSIS

Photoshop was used to count the number of black and white pixels in each sample. These pixel counts were then used to determine the area of Bi-2212 and silver in each wire. This data, along with measurements of the length, mass, and volume, were used in formulas to determine the density of the Bi-2212 in each wire.



Black & White image of 1.0 mm heat treated rectangular wire using Photoshop



Black & White image of 1.0 mm heat treated rectangular wire using Olympus microscope at 20x

CONCLUSION

Findings indicate the density of Bi-2212 increases significantly after heat treatment at 822 °C under 50 bars for 12 hours. The heat treated 1 mm diameter round wire had Bi-2212 densities at or above 70%. In addition, Bi-2212 round wire is valuable due to its flexible architecture. The rectangular wire structure theoretically provides superior conduction because of high surface area proximities, but its density remains below optimal levels. This may be due to inconsistencies in the wire fabrication process in preparation for heat treatment. Improving densities is important toward achieving significant critical current (J_c) improvements in these superconductor wires. Investigation and research should continue on the 2013 round and rectangular samples in order to improve data collection and density analysis. Heat treating Bi-2212 at greater pressure is an ongoing area of interest because it simulates the stresses of a magnetic field. This, in turn, improves and expands the practical applications of superconductors in energy production, medicine, electronics and industry.

			Green Wire		Heat Treated Wire	
Sample #	Year of Mfg.	Wire Dimensions (mm)	Avg. Wire Area (mm²)	Avg. 2212 Density (g/cm³)*	Avg. Wire Area (mm²)	Avg. 2212 Density (g/cm³)*
1, 2[a]	2005	1.085, 1.085 ϕ	0.925	4.525 (68%)		
3, 4[a]	2005	1.083, 1.085 ϕ	0.923	4.371 (66%)		
5-Rec, 6-Rec[b]	2013	0.95 x 1.36, equiv. ϕ 1.224, 1.223	1.176	2.645 (40%)		
7, 8[c]	2005	1.046, 1.046 ϕ			0.859	5.797 (87%)
9-Rec, 10-Rec[d]	2013	1.0 x 1.4, equiv. ϕ 1.212, 1.238			1.178	2.221 (33%)[e]

a - pmm050629-2 c- pmm050629-6 e – wire was not completely sealed during OP HT
b - pmm130125 d - pmm130125-7

*The theoretical density of Bi-2212 phase is 6.6 g/cm³

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[2]. J. Jiang, W.L. Starch, M. Hannion, F. Kametani, U.P. Trociewitz, E.E. Hellstrom and D.C. Larbalestier *"Doubled critical current density in Bi-2212 round wires by reduction of residual bubble density"*, Superconductor Science and Technology, June, 2011.

ACKNOWLEDGEMENT

Much appreciation to J Jiang, R Alicea and The Center for Integrating Research and Learning, and The National High Magnetic Field Laboratory for all of the support throughout the course of this program. This project was supported by NSF-DMR-1157490 and the State of Florida.