Bi-2212: The Current Density Dynamo

Jianna Dalton – RET, Rock Lake Middle School, Longwood, Florida
Michele Van Voorst – RET, Marathon Middle School, Marathon, Florida
Eric Hellsrom – Professor, Florida State University
Jianyi Jiang – Research Scientist, Applied Superconductivity Center, National High Field Magnetic Laboratory
Carlos Sanabria – Graduate Researcher, ASC, NHFML
Luis Sura - Undergraduate Research Assistant, ASC, NHFML

Introduction:

One hundred years ago (1911) the discovery was made that some metals are able to conduct electricity with no resistance when they are cooled to very low temperatures. This unique property is called superconductivity. Current research involves experimenting with conductors which will allow for the flow of greater currents at higher (warmer) temperatures.

Bi-2212 (Bi2Sr2CaCu2O8) Bismuth Strontium Calcium Copper Oxide is a ceramic superconductor. The silver sheathed Bi-2212 round wire is fabricated as a multifilamentary 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 can be used for stronger and more efficient electromagnets.

Purpose:

The purpose of this research project was to compare processing of the Bi-2212 wires in different atmospheres, and determine which gas would yield wires with the highest critical current density. Pure Oxygen and Air (20% Oxygen) were the gases the wires were heated in (at 887 °C for 12 minutes). Then the wires were quenched (quickly cooled in a brine solution) to freeze the microstructures for analysis.

Experimental Procedure:

We began with 9 wire samples that were 0.8 mm in diameter and 5.0 mm in length. These wires had all been heated at different temperatures 875°C, 879°C, 881°C, 883°C, and 887°C in air or oxygen for 12 minutes, then quenched. Using a polymer (Con ductoMet® Con duc tive Filled Phenolic Mounting Compound) and a press machine (Buehler Automatic Mounting Press Simplipimet) we created a small round disk that we then drilled holes in to place the wire samples. More polymer material was added in the press a second time to create the final puck.

The puck was then ground on a polisher with different grits of Silicon Carbide paper (starting with a coarse 340 and finishing with a fine 800 grit) to produce a smooth surface. We measured the thickness of the puck with digital callipers to ensure the surface was as flat as possible. Final fine polishing to remove any remaining scratches occurred over a 24-48 hour period in the Vibromatic automatic polishing machine. The end result was a smooth, flat surface suited to be viewed with the Scanning Electron Microscope (SEM). Using the SEM very detailed images of the transverse sections of the wire were taken. These images allowed us to view the microstructures in the wire filaments.

Analysis:

We used the image program Photoshop to analyze the scanning electron microscope images that we received. We compared two different wires (5 and 9), three bundles each, to determine the phase assemblage of the quenched wires. We used colors to identify different phases in the pictures by isolating and coloring the four different “phases” for the Bi-2212 wires.

As shown in the SEM images above, the grey matrix is silver, and the filament has four different phases, the angular dark carbonate-earth-cuprate (AEC), the round black spots (poles), the dark grey Bi-Sr-Ca-O (cooper-free), and light grey (liquid, melted Bi-Sr-Ca-O). We analyzed 3 bundles from each of the wire samples 5 and 9 both heated at the same temperature (887 °C for 12 minutes). Wire 5 was heated in air, and wire 9 heated in pure oxygen.

After the pictures were colored we used Photoshop to measure and calculate the pixel count and used Excel to complete our analysis in order to determine which samples had the fewest pores.

Conclusion:

We found that the wire sample bundles that were melted in oxygen had more AEC, pores and copper free grains in the melt state than the sample heated in oxygen. The AEC, copper-free and liquid phase will turn into Bi-2212 in the later stage of the heat treatment, but the pore will remain. The pore is a current barrier. The greater the pore area, the smaller the critical current density.

Further analysis should be conducted on the remaining wires to determine if this phase assemblage difference is the same at the different temperatures. In addition more testing should be conducted after fully processed.

Resources:

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