Chemical Interaction Between Ag-Sheathed Bi-2212 Round Wire Conductor and Alumino-Silicate Braid


Introduction
Wind-and-react Bi-2212 coils for high-field magnet applications require wire insulation that will withstand aggressive heat treatment. The current insulation is an alumino-silicate braid made of alumino-silicate fibers whose overall composition is ~73 wt% Al₂O₃ and ~27 wt% SiO₂, which is that of the mineral mullite. However, the fiber does not have the mullite structure, but rather is a mixture of crystalline Al₂O₃ and amorphous SiO₂. Previous studies show that heat treating 2212 wire with this insulation decreases $I_c$ by ~20%. We report on a study to determine what causes this $I_c$ decrease [1]. We found that Cu diffuses out from the 2212 filaments into the alumino-silicate fibers after the heat treatment. This Cu loss changes the overall composition of the outermost filaments in the 2212 wire, resulting in decreased $I_c$.

Experimental Procedures

We used round, Ag-sheathed 2212 wire from Oxford Superconducting Technologies that they braided with the alumino-silicate fibers. A vexing problem designing the experiments was maintaining intimate contact between the braid and the wire during the heat treatment. We solved this by wrapping the braid with pure Ag wire to keep the braid in contact with the 2212 wire (Fig. 1). Two types of experiments were run. One used individual pieces of wire with and without insulation; the other used a single wire with alternating ~2 cm long sections with and without insulation (Fig. 1). These were heat treated and their electromagnetic properties were measured.

Results and Discussion

The results for both types of experiments showed ~20% lower $I_c$ in wire sections in intimate contact with the braid as observed earlier (Fig. 1). Cross sectional SEM images showed the usual reaction between the alumino-silicate fiber and Ag from the Ag sheath. SEM-EDS analysis showed a small amount of Cu in the alumino-silicate fiber where it contacted the Ag sheath. $T_c$ and the irreversibility field were the same for wire sections with and without the braid. Remnant magnetization analysis showed the intergranular $I_c$ was larger in bare sections of wire than in wire in contact with the braid. During the heat treatment, Cu diffuses out of the 2212 filaments dissolving in the Ag and forming (Mg,Cu)O particles in the Ag(Mg) sheath. The EDS analysis shows the alumino-silicate braid is also a sink for Cu from the 2212 filaments. Incorporating Cu in the insulation increases the amount of Cu lost from the 2212 filaments during the heat treatment. More Cu loss leads to a larger volume fraction of copper-free phase in the outermost filaments and on cooling less 2212 can form in these affected filaments, decreasing their $I_c$. The decreased intergranular $I_c$ in sections of wire with braid shows that decreasing Cu in these filaments decreases their connectivity.

Conclusions

The alumino-silicate braid that is currently used as an insulation material when heat treating 2212 wire decreases $I_c$ ~20% compared to bare wire. This decrease in $I_c$ is due to Cu diffusing out of the 2212 filaments and through the Ag sheath to the braid during the heat treatment. These results suggest that finding a new insulation material that does not react with Cu from the 2212 filaments would increase $I_c$.

Acknowledgements

This work was supported by U. S. National Science Foundation Division of Material Research through Grant No. DMR-0654118 and the State of Florida.

References