Control of contact resistivity between REBCO tapes

Lu, J., Levitan, J., Radcliff, K., Kim, K.L., Xin, Y.,Goddard, R. and Bai, H. (NHMFL)

Introduction

No-insulation (NI) REBCO magnets have advantages of self-protection which allows significantly higher engineering current density and mechanical strength. However, NI REBCO magnets have drawbacks of long magnet charging delay time and high field-ramp-loss. These drawbacks can be mitigated by managing the turn-to-turn contact resistivity (R_c). In this research, we explored two methods of controlling R_c

Experimental

The first method of controlling R_c is to oxidize the surface of the copper stabilizer of a REBCO conductor by using a commercial oxidant Ebonol C. Optimization of the solution concentration and oxidation reaction temperature was determined experimentally in order to obtain a suitable oxide layer thickness. The second method is to treat the surface of a stainless steel tape so its R_c can be tailored to be used as co-wind material for a magnet coil. R_c results from these two methods were measured under contact pressure between 2.5 and 25 MPa at 77 K using an experimental setup developed at the NHMFL [1].

Results and Discussion

The thickness of copper oxide (Cu_xO) formed by Ebonol oxidation were measured as a function of Ebonol concentration, temperature and reaction time. Cu_xO thickness was controlled by these parameters. A cross-sectional TEM image (Fig. 1) showed that the Cu_xO layer has a fine grain structure. A reel-to-reel Ebonol oxidation machine was developed to oxidize a 15 meter long REBCO tape, which was subsequently wound into a test coil to measure R_c by discharging it and getting its magnetic field decay time constant at 77 K. R_c from this test coil was consistent with that measured by a short sample [1], which validated the short sample R_c test as a reliable method of measuring R_c of an NI magnet. In addition, in order to use room temperature coil resistance to predict R_c in a superconducting magnet, a simple numerical model was developed, and the predicted R_c agreed with experimental data reasonably well.

Using an as-received stainless steel tape as co-wind reinforcement resulted in very high R_c (on the order of 100,000 $\mu\Omega$-cm^2) due to the highly resistive native oxides on the stainless steel surface. This high R_c causes concern on coil's ability of self-quench protection. However, a light mechanical polishing or chemical etching of the stainless steel surface removes the native oxides and reduces the R_c to about 2000 $\mu\Omega$-cm^2 which remains stable after 4 months in the lab. For a large NI magnet, it is likely that the desirable R_c is above 2000 $\mu\Omega$-cm^2, which can be achieved by heating of the stainless steel tapes in air at a moderate temperature as shown in Fig. 2.

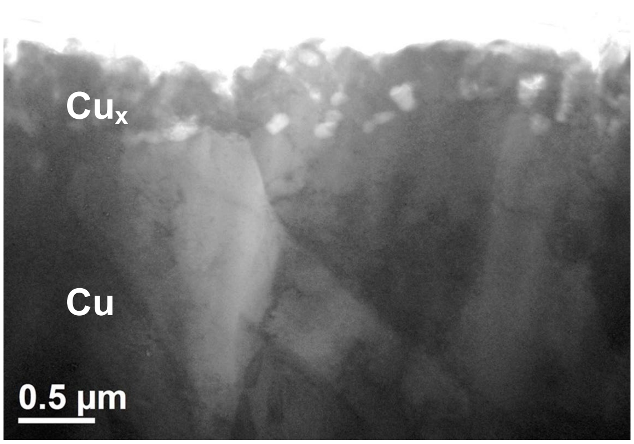

Fig.1 TEM image of a cross-section of an oxidized REBCO near surface. The oxidation was done in 20% Ebonol C solution at 98 C for 60 sec. The copper oxide layer consists of small grains, and is about 0.7 μm thick

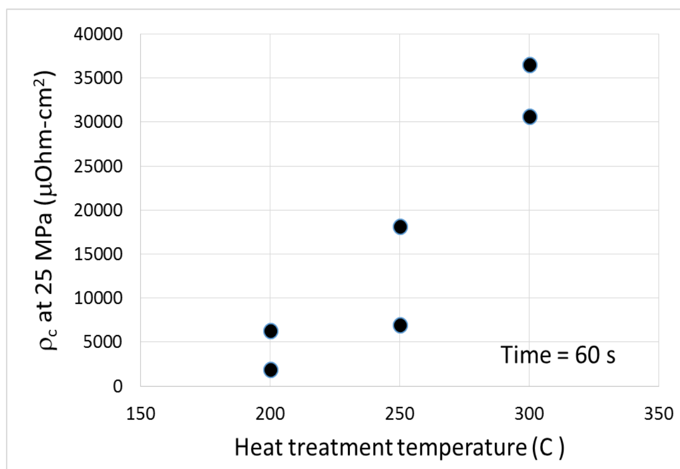

Fig.2 R_c of REBCO sandwiched with a stainless steel tape which was etched by concentrated HCl to remove the native oxides, then heated in air for 60 seconds at different temperatures.

Acknowledgements

The NHMFL is supported by NSF through NSF-DMR- 1644779 and the State of Florida.

References

[1] J. Lu, R. Goddard, K. Han, and S. Hahn, Supercond. Sci. Technol., **30**, 045005 (2017)