Bi2212 Conductor and Coil Technology for High Field Magnets

U.P. Trociewitz, Y. Jiang, E.E. Hellstrom, W.D. Markiewicz, J. Schwartz, and D.C. Larbalestier (ASC); S. Hong, Y. Huang, H. Miao, M. Meinesz, B. Czabaj (Oxford Superconducting Technology Inc., NJ); I.H. Mutlu (Harran Üniversitesi, Turkey)

Development of $Bi_2Sr_2CaCu_2O_{8+x}$ (Bi2212) conductor for high-field magnet technology applications is a focus at the Applied Superconductivity Center (ASC) [1]. A design of a high field insert magnet manufactured using Bi2212 round wire in a wind and react (W&R) approach has been developed. In its current configuration the magnet will deliver 7 T in a background magnetic field of 18 T. The magnet design consists of four sub-shells with varying amount of external reinforcement on each shell and will have a bore size of 30 mm. The wire is Bi2212/Ag-alloy, 85 x 7 multifilament wire manufactured by Oxford Superconducting Technology (OST). It has a total diameter of 1.3 mm including a 0.15 mm thick $3Al_2O_3$-$2SiO_2$ mullite fiber braid [2]. To understand and solve potential issues with thermo-processing of larger winding packs and other basic technology issues, a series of small sample-coils have been wound on mandrels made from Macor, a machinable glass-ceramic. They were heat-treated and studied regarding superconducting, and microstructural properties, as well as regarding chemical compatibility between conductor, electrical insulation and structural materials. The coils were heat-treated applying the typical three-step heat-treatment process in flowing O_2 including partial-melt, recrystallization and phase formation and phase refinery steps. Incompatibility issues were evident between the conductor, insulation braid and Macor. With all coils wound on Macor mandrels excessive leakage was found that could only be partially alleviated by changing heat treatment parameters and increase of gas flow, as shown in Figure 1. Scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS) revealed that Macor decomposes as it reacts with the conductor releasing Mg and F. It also revealed reactions between the conductor and the insulation braid causing erosion of the Ag-alloy sheath and transformation of the mullite into a brittle glass that may also reduce O_2 diffusion into the conductor that is needed to complete Bi2212 phase formation. After replacing Macor coil forms with Inconel 600 coil forms leakage almost disappeared, as seen in Figure 2. This indicates that chemical reactions play a much stronger roll in the cause of conductor leakage than other potential reasons that have been suggested previously like pre-existing defects, pin-holes, or internal pressure build up caused by the formation of CO_2 inside of the conductor. Comparison of transport data of short samples and coils show that though the conductor suffers from connectivity issues it is possible to manufacture W&R coils with decent performance. To increase packing density and hence the engineering critical current density, alternatives to the mullite braid insulation are being considered. Sol-gel coating with ZrO_2 has shown promising results in short samples and needs to be evaluated further.

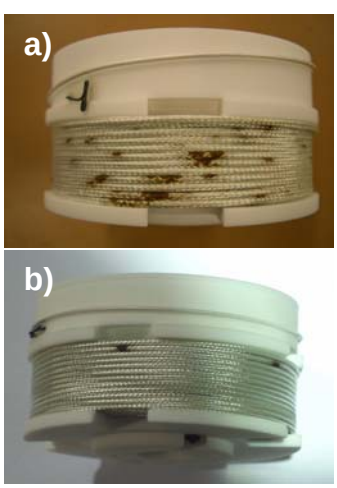

Figure 1. Bi2212 coils on Macor coil forms heat treated with a) 0.5 l, and b) with 1 l/min O_2 gas flow.

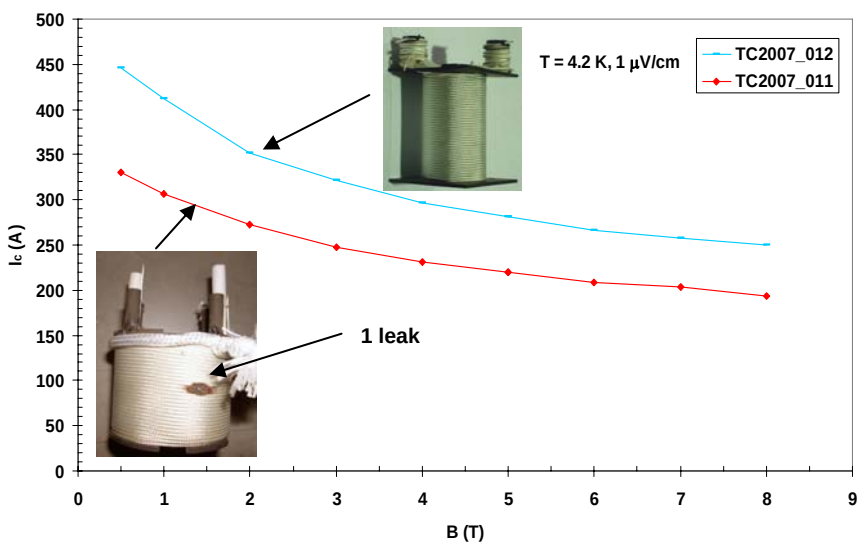

Figure2. Bi2212 coils wound on Inconel 600 coil forms and in-field transport data.

[1] Weijers, H.W., Trociewitz, U.P., Marken, K., Meinesz, M., Miao, H., Schwartz, J., Supercond. Sci. Technol. **17** (2004) 636-644.

[2] Miao H, Marken K R, Meinesz M, Czabaj B, Hong S, Twin A, Noonan P, Trociewitz U P, Schwartz J, *IEEE Trans. Appl. Supercond.* **17(2)** (2007) 2262 – 2265.