WB5-1-INV

Recent microstructural understanding to lead further J_c optimization of Bi-2223 tapes

*F. Kametani[1,2], A. Oloye[1], G. Osabe[3], S. Kobayashi[3], J. Jiang[1], E. E. Hellstrom[1,2], D. C. Larbalestier[1,2]

National High Magnetic Field Laboratory, Florida State University[1]
Department of Mechanical Engineering, Florida State University[2]
Sumitomo Electric Industries Ltd, Osaka[3]

The Bi-2223 superconducting tape is the 1st generation high temperature superconductor (HTS). Due to its high T_c ~110 K, the devices made of Bi-2223 can be operated at the liquid nitrogen temperature 77 K. Especially the application of power electric utilities such as long distance power transmission cables have been investigated. Also this material is very attractive for high field magnets, since the irreversibility field (H_{irr}) becomes more than 20-30 T below 15-20 K. It has been more than a decade since Bi-2223 wires were industrialized. However, few times increase of the critical current density J_c is required in order to expand its practical applications and to make a substantial cost reduction of Bi-2223 wires. As a conductor, Bi-2223 is the most mature HTS, but in reality, there are so many unknown parameters in the manufacturing process because of the fact that Bi-2223 consists of 6 elements. In particular, the detailed structure of grains and grain boundaries and their correlations to J_c are still elusive. In recent years, we utilized high resolution Electron Backscatter Diffraction Orientation Imaging Microscope (EBSD-OIM) to visualize the grain structure in the industrial grade and proto type of Bi-2223 superconducting tapes. We found that the Bi-2223 grains are not stacked as the perfect brick wall model, but rather in the way that the c-axes are slightly tilted with a slight out-of-plane misorientation. The better out-of-plane grain alignment resulted in 24 % J_c increment. The in-plane grain orientations appear macroscopically random, but some of grains tend to form the domain structure in which the grain boundaries appear far less detrimental for J_c than previously thought. In this presentation, we will compare such microstructural features of Bi-2223 tapes and its sibling Bi-2212 round wires, and discuss the next challenge to further improve the J_c of Bi-2223 tapes.

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Local-vs.-Global Current-Voltage Characteristics in HTS Tapes

*Takanobu Kiss[1], Lin Lyu[1], Takumi Suzuki[1], Kohei Higashikawa[1]

Kyushu University[1]

It is well established that a current-voltage (I-V) characteristics in HTS tape is generally rounded typically characterized by a power law model due to sever influence of thermal fluctuation and/or random pin distribution. It is crucial, therefore, to take into account such rounded I-V characteristics as a function of external magnetic field and temperature for a design of HTS based device. Generally, such I-V characteristics are measured by the four-probe method using a short piece sample or micro-bridge, then used as a design parameter of a coil or magnet, whereas an actual tape length in a device is in the scale of hundreds of meters or longer. However, the influence of a spatial variation on its I-V characteristics in a long length tape is not yet clear. In this study, we have investigated the relationship between a local I-V characteristics and a global one based on a measurement of reel-to-reel local Ic measurements and measurements on position dependent I-V characteristics of HTS tapes in both Bi-2223 and RE-123. Relationship among the power law I-V characteristics in local measurements, spatial variation of Ic and n-index, and the influence of flux pinning and thermal fluctuation will be clarified.

This work was supported by JSPS KAKENHI Grant Number 19H05617 and the New Energy and Industrial Technology Development Organization (NEDO).

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Magnetic microscopy for NbTi-Bi2223 superconducting joints impregnated with different PbSn-based solders

*Zeyu Wu[1], Kohei Higashikawa[1], Ryo Matsumoto[2], Yoshihiko Takano[2], Takanobu Kiss[1]

Kyushu University, Japan[1]
National Institute for Materials Science, Japan[2]

LTSs have been widely used in superconducting magnet application such as NMR spectroscopy and MRI. For a breakthrough in high magnetic field generation, HTSs are inevitable. However, to realize a practical high field magnet system, a superconducting joint between LTS and HTS is a key component to realize persistent mode operation. It was reported that a superconducting joint between NbTi wire and Bi2223 tape can be fabricated via the in-situ sheath-dissolution method using PbSn-based solder. Critical current (I_c) of the joint was measured by four probe method, which is dependent on the solder composition [1]. However, the influence of the local superconducting property and a limiting factor of the joint are not yet clear from such macroscopic measurement. Furthermore, it should be clarified the superconducting property at extremely low electric field criterion equivalent to the persistent mode operation. In this study, we have investigated spatial distribution of local critical current density (J_c) in the joint based on magnetic microscopy, to clarify the influence with different solder composition.

The magnetization current distribution of two superconducting joints impregnated with $Pb_{0.7}Sn_{0.3}$ and $(Pb_{0.7}Sn_{0.3})Bi_{0.4}$ was evaluated respectively. As a result, J_c around the NbTi shows high performance, while the J_c of Bi2223 is low in both samples. Difference between the two samples can be observed as follows. Firstly, the J_c of $Pb_{0.7}Sn_{0.3}$ solder is lower than that of $(Pb_{0.7}Sn_{0.3})Bi_{0.4}$ solder. Secondly, the magnetization current can flow across both edges of the Bi2223 impregnated with $(Pb_{0.7}Sn_{0.3})Bi_{0.4}$, while there is almost no current observed in the Bi2223 impregnated with $Pb_{0.7}Sn_{0.3}$. In addition, we measure the J_c distribution along the longitudinal direction of the Bi2223, showing low J_c and poor joint with the $Pb_{0.7}Sn_{0.3}$ solder similar to the in-plane distribution.

In summary, by visualizing the J_c distribution based on magnetic microscopy, we can conclude that the difference between two samples comes from the different superconducting property of the solders and the performance of Bi2223-solder joint. Furthermore, Bi2223 tape is the limiting factor of I_c in both samples.

This work was supported by the JST-MIRAI Program, JPMJMI17A2.

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WB5-4

Nanostructural Characterization of Jointed $GdBa_2Cu_3O_y$ Coated Conductors Using $YBa_2Cu_3O_y$ Intermediate Layer

*Takeharu KATO[1], Ryuji Yoshida[1], Daisaku Yokoe[1], Kotaro Ohki[2], Tatsuoki Nagaishi[2], Yoshinori Yanagisawa[3], Hideaki Maeda[3,4], Tsukasa Hirayama[1], Yuichi Ikuhara[1,5]

Nanostructures Research Laboratory, Japan Fine Ceramics Center[1]
Sumitomo Electric Industries, Ltd.[2]
RIKEN Center for Life Science Technologies[3]
Japan Science and Technology Agency[4]
The University of Tokyo[5]

Recently a high temperature superconducting joint between $GdBa_2Cu_3O_y$ (GdBCO) coated conductors (CCs) was achieved using a GdBCO intermediate layer [1,2]. Using this joint technique and GdBCO coated conductors, a nuclear magnetic resonance (NMR) system was developed [3]. The NMR system was operated in a persistent-current mode in a magnetic field of 9.39 T at 4.2 K and detected NMR signals clearly. Instead of the GdBCO intermediate layer, an $YBa_2Cu_3O_y$ (YBCO) intermediate layer were applied to GdBCO jointed CCs to investigate the interface structures between CCs and the intermediate layer. An alcoholic solution of fluorine-free metallo-organic complexes with a Y:Ba:Cu molar ratio of 1:2:3 was spin-coated on one GdBCO CC. A spin-coated film was decomposed at 500℃ and microcrystallized at 800℃. The microcrystallized film and another GdBCO CC were pressed together and heated up to 800℃ for 20 min in an oxygen atmosphere to make superconducting joint named iGS® (intermediate Grown Superconducting) joint. We observed nanostructures of the GdBCO jointed CC using the YBCO intermediate layer by scanning electron microscopy (SEM) and (scanning) transmission electron microscopy ((S)TEM). Both of the GdBCO layers were connected to the YBCO intermediate layer. In addition, the *c*-axis of both the GdBCO layers and the YBCO grains composed of the intermediate layer were well aligned. Energy dispersive X-ray spectroscopy analysis indicated that the YBCO grains included Gd elements, which were considered to replace with Y elements in the YBCO. In addition, high angle annular dark-field image suggested that the distribution of the Gd elements in Y site in the intermediate layer was inhomogeneous. Those Gd elements were considered to be diffused from the GdBCO layers into the microcrystallized film (precursor of the intermediate layer) on the GdBCO layers during the iGS® joint process at 800℃. YBCO grains containing Gd in the intermediate layer would grow epitaxially on the GdBCO surfaces at the same time.
This work was supported by JST-Mirai Program Grant Number JPMJMI17A2, Japan.

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Keywords: HTS joint, iGS, TEM, STEM

WB5-5

Performance Evaluation of Practical REBCO CC Tapes for Superconducting Coils for Wind Power Application

*Mark A. Diaz[1], Madlene Velasco[1], Michael de Leon[1], Hyung-Seop Shin[1], Satoshi Awaji[2]

Andong National University[1]
IMR Tohoku University[2]

A Korea-type 10 MW-class large scale superconducting power generator with floating offshore wind power system which incorporates high-temperature superconducting (HTS) 2G coated conductor tapes for race-track coils are developing. Their operation conditions will be in a temperature range from 20 to 40 K and under a magnetic field of 2 T. Therefore, it is needed to investigate mechanical and electromechanical properties of commercially available practical REBCO CC tapes under the superconducting wind power application conditions. In this study, the electromechanical performance of differently processed REBCO CC tapes was evaluated at both test conditions of 77 K/self-field and 35 K/2 T using 4 mm wide and 12 mm wide REBCO CC tapes, respectvely. In addition, in the aspect of reliability assessment, the I_c degradation behaviors of 12-mm wide IBAD/RCE-DR Cu-stabilized GdBCO CC tapes using high-cycle fatigue test were investigated at 77K and at a stress ratio, R = 0.1. The correlation between the mechanical and electromechanical performances of practical REBCO CC tapes under specified test conditions were examined.

This research was supported by the Korea Electric Power Corporation. (Grant number: R18XA03).This work was partially supported by a grant from National Research Foundation of Korea (NRF-2017-001109), funded by the Ministry of Science and ICT (MSIT), Republic of Korea.

Keywords: REBCO coated conductor, Electromechanical performance, Reliability, Superconducting coils for wind power

WB5-6

Progress in High-Speed Spin Testing of Superconducting Wire and Tapes for High-Field NMR Magnet Qualification

*John Voccio[1], Phillip Curtsmith[1], C J Favazza[1], Josh Boyle[1], Connor Allen[1], Matthew Franchi[1], Nicholas Tetreault[1]

Wentworth Institute of Technology[1]

This paper summarizes the status of a 3-year, NIH-funded research project to study the strength of high temperature superconductors under high circumferential hoop stress, in order to qualify these materials for high-field (> 1 GHz-class NMR magnets. The unique approach presented here is to spin test coils at high rotational speeds, approaching 100,000 rpm, in order to induce the necessary hoop stress. In this initial trial, short lengths of 2G YBCO thin-film tapes and reinforced Bi-2212 wires were mounted to a 75-mm diameter test rotor and spun. The results of this experiment, along with progress in building a second, higher speed rotor, are presented in this paper.

Keywords: superconductors, NMR, spin testing