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An Intermediate Grown Superconducting (iGS) Joint between REBCO Coated Conductors: Fabrication, Microstructure and Superconducting Properties

*Kotaro Ohki[1], Tatsuoki Nagaishi[1], Takashi Yamaguchi[1], Yoshinori Yanagisawa[2], Renzhong Piao[2], Hideaki Maeda[2], Takeharu Kato[3], Daisaku Yokoe[3], Tsukasa Hirayama[3], Yuichi Ikuhara[3,4], Hitoshi Kitaguchi[5], Takeshi Ueno[6], Kazama Yamagishi[6], Tomoaki Takao[6]

Sumitomo Electric, Japan[1]
RIKEN, Japan[2]
Japan Fine Ceramics Center, Japan[3]
University of Tokyo, Japan[4]
National Institute for Materials Science, Japan[5]
Sophia University, Japan[6]

Over the past few years, several studies have been performed on the superconducting joint of $REBa_2Cu_3O_y$ (REBCO, RE: rare earth elements) coated conductors (CCs) which is one of the key technologies to realize persistent current operations of prominent HTS magnets [1, 2]. Park has succeeded in the superconducting joint of REBCO CCs [1]. However, the total processing time is too long for large coil applications such as nuclear magnetic resonance (NMR) and magnetic resonance imaging (MRI).

We have developed a novel superconducting joint technology for REBCO CCs. It uses a joining strap with a microcrystalline REBCO precursor layer. The joint technology has an advantage of a sufficiently short total processing time of less than one day. The joining strap and the GdBCO CCs were heated at 800 °C for 20 min. in an atmosphere of 100 ppm oxygen to make the polycrystalline GdBCO on the joining strap grow epitaxially. This intermediate grown superconducting (iGS) joint gives a critical current of > 100 A at 77 K in a self-field.

Cross sectional investigation of the joint area was carried out by a scanning electron microscope (SEM) and a transmission electron microscope (TEM). An SEM image indicates that there are some voids and inclusions, such as CuO and Gd_2O_3, in the joint area. In spite of the voids and the inclusions, approximately 60% of the superconducting layers were directly connected. Furthermore, a high resolution image obtained by the TEM shows that the microcrystal grows epitaxially and the boundary of the GdBCO layers of the CCs and the GdBCO layer of the joining strap were atomically connected with the grown intermediate layer. It was estimated from the persistent field decay curve that a joint resistance was in the order of 10^{-12}–10^{-13} at 77 K in a self-field over three days, with an operating current of ~10 A (~14% of the calculated coil critical current).

In this presentation, the magnetic field dependence of the critical current will be shown. We believe the superconducting joint technology is promising for realization of the persistent current mode operation of NMR and MRI.

[1] Park Y, Lee M, Ann H, Choi Y H and Lee H 2014 NPG *Asia Materials* **6** e98.
[2] Jin X, Yanagisawa Y, Maeda H and Takano Y 2015 *Supercond. Sci. Technol.* **28** 75010.

Keywords: REBCO-coated conductor, superconducting joint, microcrystalline precursor intermediate, microstructure

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Superconducting joint of REBCO wires for MRI magnet

*Shinichi Mukoyama[1], Akinobu Nakai[1], Hisaki Sakamoto[1], Shinji Matsumoto[2], Gen Nishijima[2], Mamoru Hamada[3], Kazuyoshi Saito[3], Yasuyuki Miyoshi[3]

Furukawa Electric Co., Ltd.[1]
National Institute for Materials Science[2]
Japan Superconductor Technology, Inc.[3]

High temperature superconducting wires (HTS wires) are promising for superconducting magnet applications because it is operated at higher temperature than liquid helium temperature. Particularly, a MRI magnet using the HTS wires is expected to obtain light-weight, compact and low operation cost. The HTS MRI magnet needs a technology of the persistent current mode. However, a superconducting joint of HTS wires has not been realized stably at this time.
We have developed a superconducting joint by using commercial REBCO tapes, and the superconducting joint with 10^{-12} ohm and 100 A-class was achieved by a direct-contact between superconducting layers of two REBCO wires. Moreover, a measurement equipment of low joint resistance was developed by measuring decays of magnetic field in the one-turn-loop that consisted of a REBCO wire and a superconducting joint.

Keywords: REBCO wire, superconducting joint, persistant current mode, MRI magnet

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Magnetic Field Stability in the Persistent Current Operation of the REBCO Coil with a Superconducting Joint

*K. Takahashi[1], T. Hase[1], S. Awaji[1], A. Nakai[2], S. Yamano[2], H. Sakamoto[2]

Institute for Materials Research, Tohoku University, Sendai 980-8577, Japan[1]
Furukawa Electric Co., Ltd., Ichihara 290-8555, Japan[2]

HTS superconducting magnets for MRI and NMR should be operated in a persistent current mode in order to achieve high temporal stability of the magnetic field of less than 1 ppm/h. Persistent current operation techniques of an HTS coil, however, have not been established yet. A persistent current switch (PCS) and a superconducting joint are the key technologies for persistent current operation. Recently, Furukawa Electric Co., Ltd. has successfully developed the superconducting joint technology with a resistance on the order of 10^{-12} Ω and a PCS using REBCO tapes, connected with a REBCO double pancake coil. In this paper, we report detail results of persistent operation tests of the system including a superconducting joint, a PCS and a pancake coil fabricated with a REBCO tape in a self-field and an external magnetic field of 1 T at 20 K. The persistent current system was fabricated with a SuperPower REBCO tape that had a dimension of 6 mm width and 0.1 mm thickness. The REBCO double pancake coil had 80 × 2 turns with the inner and outer diameters of 44 and 68 mm, respectively, and the inductance of 1.54 mH. The persistent current system was conduction-cooled by a 4K-GM cryocooler in the cryostat installed in a 220 mm room temperature bore of a cryogen-free superconducting magnet. The current decay behavior in persistent current operations up to 170 A were measured using a Hall probe located at the center of the coil. The decay rate of the magnetic field after five days operation was evaluated to be 1.7 ppm/h for the excitation current of 170 A in the self-field. The voltage-current characteristics obtained from decay curves of the magnetic field indicate that the decay behavior of persistent current are dominated by the joint resistance in 1 T but by the shielding current in the self field.

Keywords: Persistent current operation, REBCO coil, Shielding current, Superconducting joint

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Enhancement of Joint Properties of Various Ultrasonic Welded CC Joints

*Hyung-Seop SHIN[1], Chan Hun Jung[1]

Andong National University, Andong, 36729 Korea[1]

As a means to produce long-length high temperature superconducting wires with relatively uniform current capacity along its length, a new joining technology of 2G coated conductor (CC) tapes based on an ultrasonic welding (UW) was developed. The UW CC joining technique showed a good adhesion without any **damage to the superconducting film layer and with an acceptable low joint resistance, making it reliable and reproducible.** Recently, we attempted to achieve a low joint resistivity through the optimization of joining parameters for UW including horn tip patterns, an introduction of pre-Sn plating and a hybrid welding (HW) which incorporates soldering to the UW. **Particularly, these methods are very effective for practical applications of CC joints using the UW technique because of its shorter welding time and in an easier way, and applicable to in-line process. The method can be satisfactorily applicable to various joint structures of lap- and butt-joint for** Cu-stabilized **CC tapes, and bridge joint for CC coils based on the UW process.** In this study, in order to characterize the joint properties of the resistive CC joints fabricated by various joining methods, the joint resistivity and the electromechanical properties were evaluated at 77 K, respectively. The electromechanical testing was performed under both loading conditions of uniaxial tension and double bending at 77 K and self-field, respectively. The irreversible tension load limit and the minimum bending diameter against the retained I_c and joint resistance R_j degradation for various CC joints were determined, respectively, and the n value behaviors were also examined.
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Keywords: coated conductor, ultrasonic welding, joint structure, electromechanical properties