WBP8-1

Highly reinforced, low magnetic and biaxially textured super high tungsten Ni-W alloy composite substrates used in coated conductors

*Yaotang Ji[1], Hongli Suo[1], Lin Ma[1], Zili Zhang[2], Min Liu[1], Jin Cui[1], Xinyu Wu[1], Chenxi Zhang[1]

Key Laboratory of Advanced Functional Materials, Ministry of Education, College of Materials Science and Engineering, Beijing University of Technology, 100 Pingleyuan, Chaoyang District, Beijing 10012[1]
Institute of Electrical Engineering, Chinese Academy of Sciences, Beijing 100190, China[2]

Highly reinforced, low magnetic and biaxially textured super high tungsten Ni-W alloy substrates have been fabricated through composite substrate preparation method used in coated conductor applications. The content of tungsten exceeds 10% in the obtained substrates, which is the current world record. In this excellent super high tungsten substrate (Ni10W), it has a strong cube texture of 98.7%(<10°) as commercial Ni5W substrate, but overwhelming high yield strength of 310 MPa – twice of Ni5W substrate. Meanwhile, the saturation magnetization of the Ni10W substrate is only 4% of the Ni5W substrate. Furthermore, through the in-situ EBSD tensile observation of the stability of the strip, it is found that the grain orientation and grain boundaries of the substrate present very high stability up to 0.2 % strain, which is beneficial to the roll-to-roll preparation of the coated conductor. A CeO_2 buffer layer was successfully deposited on the super high tungsten substrates, which indicates that the substrates are suitable for REBCO coated conductors. The super high tungsten substrate with strong cube texture, high yield strength and negligible magnetization can significantly improve the progress of using the RABiTS route in the fabrication of REBCO tapes. Meantime, the mechanisms of the cube texture evolution and tungsten diffusion in super high tungsten substrate are also studied.

Keywords: Super high tungsten, Substrates, Coated conductors, Cube texture

WBP8-2

Laser scribing of stacked coated conductors laminated with solder

*Takato Machi[1], Akira Ibi[1], Takanobu Kiss[2], Masataka Iwakuma[2], Teruo Izumi[1]

National Institute of Advanced Industrial Science and Technology[1]
Kyushu University[2]

We have studied the multi-filamentary structure in the stacked coated conductors(CCs) laminated with solder by laser scribing. When the filament-width is comparably narrow with the size of defects, the defects act as origin of filament-Ic degradation. This is the reason for low yield of scribed tapes. The objective of this study is to reduce the probability of the filament-Ic drop. The laser scribing was performed for the specimens that laminated a normal CC to the artificially defect introduced CC. As a result, it was found that a certain critical current can be obtained even in a filament with defects. This work was supported by NEDO.

Keywords: coated conductors, laser scribing

WBP8-3

Fabrication of $YBa_2Cu_3O_y$ coated conductor by Vapor-Liquid-Solid growth technique using Reel-to-Reel system

*Kento Yasuda[1], Tomohiro Ito[1], Yuji Tsuchiya[1], Yusuke Ichino[1], Yutaka Yoshida[1]

Nagoya university[1]

In fabricating $REBa_2Cu_3O_y$ (REBCO) superconducting coated conductors (CCs), in order to reduce the production cost, it is necessary to increase deposition rate. However, when using PLD method, the crystallinities of the REBCO layer are deteriorated by increasing the deposition rate. From our early studies, by using VLS (Vapor Liquid Solid) growth technique, we found that VLS growth technique was possible to achieve both favorable crystallinities and high deposition rate[1]. However, previous reports on VLS growth technique are using a static system without the substrate transportation during the YBCO film deposition, so it is difficult to prepare long REBCO CCs. In this study, we extended the VLS growth technique for fabricating YBCO CCs by using Reel-to-Reel (RtoR) system with substrate transportation.

REBCO CC using the VLS growth technique consists of three layers of solid layer, liquid layer and vapor layer. When a YBCO CC is fabricated by VLS growth technique using the RtoR system, the liquid layer is solidified since the substrate is away from the heater after the liquid layer deposition. Therefore, we examined whether the solidified liquid layer would be melted by re-approaching to the heater. Fig. 1 shows X-ray diffraction patterns of the VLS-YBCO thin films re-approaching the heater at different transfer-speeds of 1.8 and 3.6 m/h. In the case of 1.8 m/h, no $BaCuO_2$(600) peak appeared due to re-melting the liquid layer. On the other hand, when transfer-speed was 3.6 m/h, there was $BaCuO_2$(600) peak. This fact indicates that the solidified liquid layer is not able to re-melt because the substrate temperature was not able to follow the heater temperature due to the high transfer-speed.

Fig. 2 shows liquid layer thickness dependence of J_c at each solid layer thickness. The total film thickness about 1.8 µm. With reducing the thickness of the solid layer and the liquid layer, we achieved 2.04 MA/cm^2 at overall deposition rate 17 nm/s. This result indicates that the thin solid layer provided good seed crystal without *a*-axis grains and the reducing liquid layer thickness suppresses melt-back of the seed layer to the liquid layer.

This work was partly supported by JSPS (19K22154), JST-ALCA,JST-A-STEP and Power Academy. The metal substrates were provided from AIST.

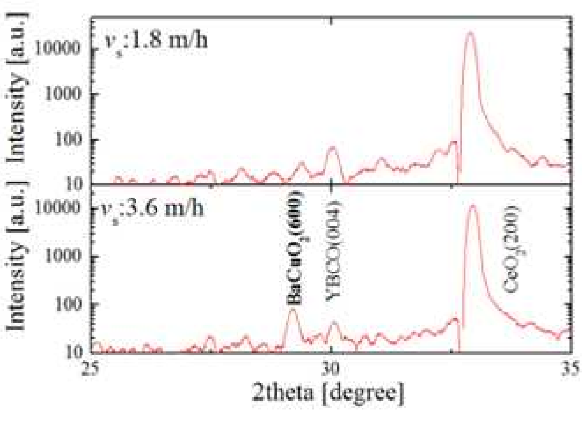


Fig. 1 X-ray diffraction patterns of VLS-YBCO CCs re-approaching to the heater at transfer speeds of 1.8 and 3.6 m/h.

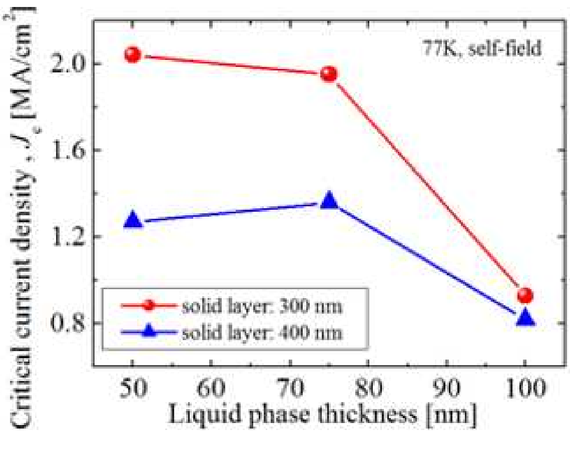


Fig. 2 Liquid layer thickness dependence of J_c at each solid layer thickness.

[1] T. Ito *et al.*: Abstracts of CSSJ conference, Vol.96, p.31 (2018)

Keywords: REBCO, Vapor-Liquid-Solid growth technique, Reel-to-Reel system

WBP8-4

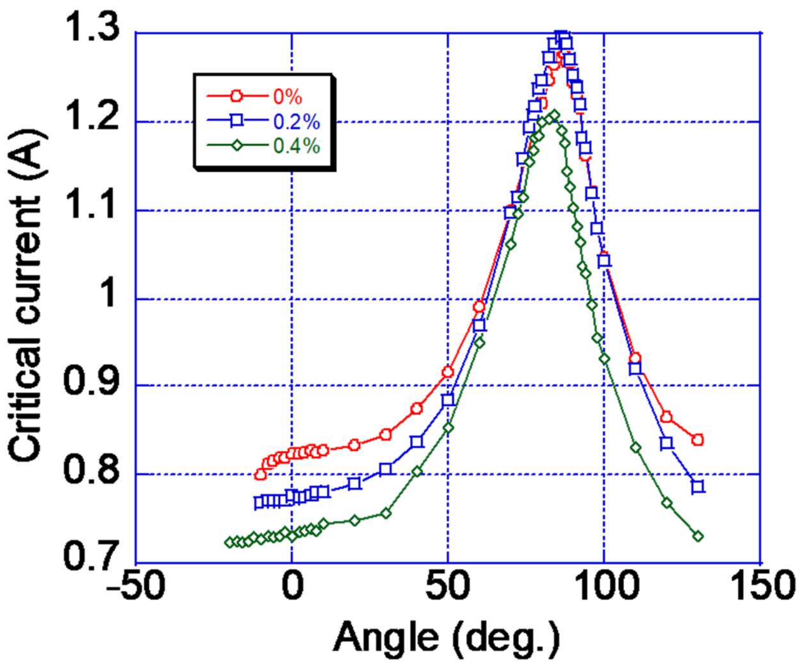
Angular dependence of critical current for REBCO coated conductor under various bending strains

*Kazuhiro Hatano[1], Hidetoshi Oguro[1], Masashi Miura[2], Yusuke Ichino[3], Yoichi Kamihara[4]

Tokai University[1]
Seikei University[2]
Nagoya University[3]
Keio University[4]

$REBa_2Cu_3O_y$ (REBCO, RE = Y, Gd, Sm, Nd, etc) coated conductors are expected to be applied to high magnetic field superconducting magnets because the conductors have very high mechanical properties and high superconducting properties even in a high magnetic field. In addition, it is well known that the critical current of REBCO coated conductors follows an almost parabolic dependence as a function of axial strain [1]. In this study, we focused on the strain effect of the REBCO. In order to improve critical current of the REBCO coated conductors using the strain effect, the relationship between strain and critical current was investigated. A superconducting properties measurement device in various environment was developed. The device can measure critical current at low temperature, various magnetic field and various field angles under bending strains.

The GdBCO coated conductor, produced by Fujikura, with 0.2 mm micro-bridge was prepared. The angular dependences of critical currents for GdBCO coated conductors under various bending strains are shown in Fig. 1. The critical currents at various magnetic field angles and bending strains were estimated by the new device. We found that the critical current at angle of 90º under 0.2% bending strain has a little enhancement by the strain. This behavior is different from the strain effect at angle of 0º.



Keywords: REBCO, Bending strain, Angular depndence, Critacal Current

WBP8-5

Study on $(Nd_xSr_{1-x})TiO_3$ thin film as conductive buffer layer for low-cost REBCO wire

*Seiya Inoue[1], Masaki Kabeya[1], Keisuke Ota[1], Ataru Ichinose[2], Toshiya Doi[1]

Kyoto University[1]
Central Research Institute of Electric Power Industry[2]

To develop low-cost REBCO superconducting wires, we have developed a new architecture using conductive rather than insulating buffer layers, combined with {100}<001> textured pure Cu tape to form $YBa_2Cu_3O_7$/Nb-doped $SrTiO_3$/Ni/Cu/stainless steel tape. In this structure, the textured pure Cu tape is expected to work not only as the template for YBCO biaxial crystal alignment but also as the stabilizing layer. We fabricated YBCO/$Sr(Nb_{0.15}Ti_{0.85})O_3$/Ni/Cu/SUS316 short sample with the J_c of 2.5 MA/cm^2 (at 77 K, self-field), and also confirmed that some current flowed into the Cu tape through the conductive buffer layers when the current exceeded the critical current of the YBCO layer [1]. However, although the resistivity of $Sr(Nb_{0.15}Ti_{0.85})O_3$ was assumed to be approximately (1.2–8.6) × 10^{-3} ohm-cm at 77 K before the YBCO deposition, the resistivity of $Sr(Nb_{0.15}Ti_{0.85})O_3$ layer in the YBCO/$Sr(Nb_{0.15}Ti_{0.85})O_3$/Ni/Cu/SUS316 increased to be few ohm-cm after the YBCO deposition and/or oxygen annealing. Because lower resistivity of the conductive buffer layer is favorable, we tried to suppress the increment of the resistivity during the YBCO deposition and oxygen annealing. In this study, we applied $(Nd_xSr_{1-x})TiO_3$ to the conductive buffer layer instead of $Sr(Nb_{0.15}Ti_{0.85})O_3$.

The electrical resistivity of the as-grown $(Nd_{0.1}Sr_{0.9})TiO_3$ thin film prepared on $LaAlO_3$ single crystal substrate by a PLD method was 4.55×10^{-2} ohm-cm at 77 K. $(Nd_xSr_{1-x})TiO_3$ and YBCO layers were prepared by a PLD method on the Ni-electroplated Cu/SUS316 tape. Fig.1 (a) and (b) show X-ray {110} pole figure and SEM image of the $(Nd_{0.1}Sr_{0.9})TiO_3$ thin film prepared on the Ni/Cu/SUS316. We can see that the $(Nd_{0.1}Sr_{0.9})TiO_3$ film had excellent biaxially crystal orientation and smooth surface. Fig. 1 (c) shows X-ray (102) pole figure of the YBCO prepared on the $(Nd_{0.1}Sr_{0.9})TiO_3$/Ni/Cu/SUS316. We confirmed that the YBCO also had excellent biaxially crystal alignment.

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[1] Doi et al., appl. Phys. Express 12 (2019) 023010.

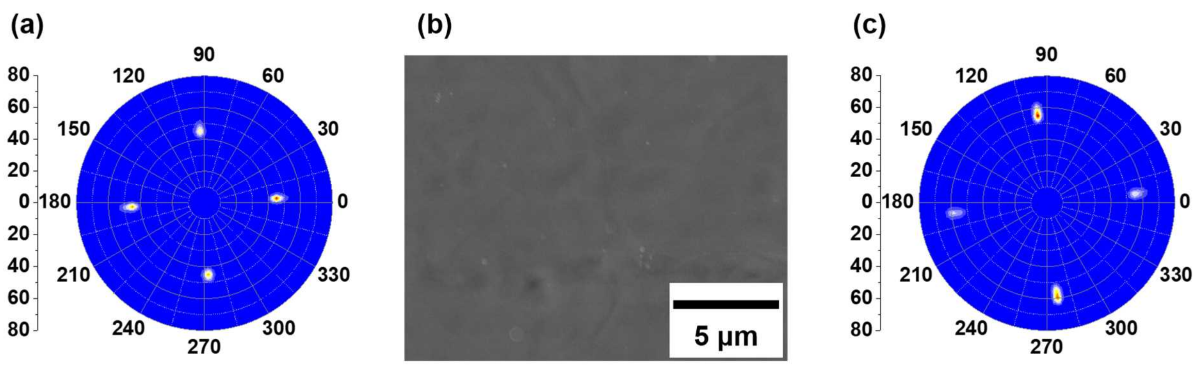

Fig.1(a) X-ray {110} pole figure and (b) SEM image of the $(Nd_{0.1}Sr_{0.9})TiO_3$ prepared on the Ni/Cu/SUS, and (c) X-ray (102) pole figure of the YBCO prepared on the $(Nd_{0.1}Sr_{0.9})TiO_3$/Ni/Cu/SUS.

Keywords: conductive buffer layer

WBP8-6

Influence of Different Narrowing Methods on Critical Current of 1 mm HTS Tapes

*Mengxin She[1], Longbiao Wang[1], Zhuyong Li[1], Zhuyong Hong[1]

Department of Electrical Engineering, Shanghai Jiao Tong University, No.800 Dongchuan Road, Minhang District, Shanghai, 200240, China[1]

Over the past decade, a great progress has been achieved in terms of performances of high temperature superconducting (HTS) tapes, such as the critical current of the tape with 4 mm width exceeds 200 A. Due to the high critical current, the narrowing process to 1 mm width for the HTS tape became a feasible technology, and the value of critical current for the 1 mm tape is able to above 50 A. The 1 mm width tape is firstly suggested by our group in 2016, and a soldered-stacked-square (3S) wire is also fabricated based on the 1 mm tape. However, during the narrowing process, some loss of critical current was observed in many experiments. This significantly affects the stable fabrication of the 3S wire. To understand the influence of narrowing process on critical current, we proposed two narrowing methods to manufacture the 1 mm tapes, mechanical cutting and laser cutting methods in this paper. Meanwhile, the soldering tin plating process is also considered in the manufacturing process of 1 mm tape. The critical current measurements were carried out in order to make a comparison with these two methods. The detailed results about the critical current measurement experiment, the microscope observation experiment, and the soldering tin plating process are presented and discussed in this study.

WBP8-7

Effect of extra addition of Ba into $YBa_2Cu_3O_{7-δ}$ coated conductor with $BaHfO_3$

*Shin Yamada[1], Ryo Teranishi[1], Yukio Sato[1], Kenji Kaneko[1], Masayoshi Inoue[2]

Kyushu University, Japan[1]
Fukuoka Institute Of Technology, Japan[2]

Critical current density (J_c) of $YBa_2Cu_3O_{7-δ}$ (YBCO) film in magnetic fields can be enhanced by introducing $BaHfO_3$ (BHO) flux pinning centers into the film [1]. In order to increase J_c, the YBCO films are fabricated by a metal organic deposition method using chemical solution with Ba deficient composition [2]. In this case, about 1 μm sized CuO precipitates were formed on the film surface due to the Ba deficient in our previous study [3]. In this study, we added extra Ba into the starting solution to compensate the shortage of Ba and investigated the influences of this Ba addition on the surface morphology.

Starting solution contains elements of Y, Ba, and Cu with molar ratio of 1 : 1.5 : 3. Two types of solution were prepared using the starting solution; one is added Hf of 10 mol% (indexed as Hf10), and another one is added both Hf and Ba of 10 mol% (indexed as Hf10-Ba10). These two solutions were spin-coated onto $CeO_2/LaMnO_3/MgO/Gd_2Zr_2O_7$/Hastelloy substrates separately, then the coated films were calcined to prepare precursor films at 430 °C in O_2 gas flow. Finally, the precursor films were crystallized to prepare YBCO at 780 °C in mixed gas flow of Ar and O_2. Surface morphology and elemental mapping of the samples were observed by a scanning electron microscopy (SEM) and an energy dispersive X-ray spectroscopy (EDS).

Fig. 1 shows SEM images and EDS elemental distribution maps of Cu and O for the samples prepared from each solution. CuO precipitates were observed on the sample surface in both films, whose sizes were almost the same. Table 1 shows the comparison of number density of CuO precipitates seen in Fig. 1 for each sample. CuO precipitates of Hf10-Ba10 decreased by about 60% compared to Hf10. It is suggested that extra addition of Ba is effective to suppress the formation of CuO.

[1] S. Engel et al Appl. Phys. Lett. 90 (2007) 102505
[2] K. Nakaoka et al Physica C 463 (2007) 519-522
[3] S. Yamada et al ISMMM Program Book (2018) 44

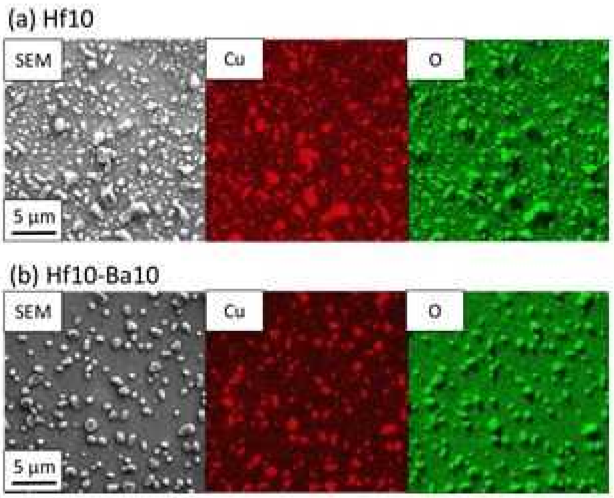

Table 1 Comparison of number density

	Number density (cm^{-2})
(a) Hf10	$1.75x10^6$
(b) Hf10-Ba10	$6.77x10^5$

Fig. 1 SEM images and EDS mappings of sample surface.

Keywords: YBa2Cu3O7-δ , BaHfO3, Flux pinning center, Extra addition of Ba

WBP8-8

Development of artificial cracked RE123-coated conductor for realizing compatibility of critical current improvement and diamagnetism reduction

*Shintetsu Kanazawa[1], Yukihiro Kawamura[1], Chihiro Sekine[1]

Muroran Institute of Technology[1]

The filamentation of tape shaped RE123-coated conductors is important to reduce the shielding current and Ac loss in the wire and coil, but the critical current is usually decreased [1]. To increase the critical current, a method is artificial pin doping, however, it is ineffective on reducing of the shielding current or AC loss. Realizing compatibility of critical current improvement and AC loss reduction is important to develop a high field magnet and highly-efficient AC devices. To achieve both, we suggested an artificial cracked RE123-coated conductor. In last year, we reported the development of split wire with 16-main-core by electrical separating by bending stress (ESBS) method [2]. In this study, the wire was fabricated with tear stress along width direction of the wire, then the cracks were formed along longitudinal direction of wire. In experiments, several samples were prepared, and the critical current was increased 14% than the original wire at 0.7 T, with great decreases of diamagnetism (shielding current). The fabrication method and the results will be discussed in upcoming ISS2019 at Kyoto.

[1] Xinzhe Jin, Hidetoshi Oguro, Yugo Oshima, Tetsuro Matsuda and Hideaki Maeda, "Development of a $REBa_2Cu_3O_{7-\delta}$ multi-core superconductor with “inner split” technology," Superconductor Science and Technology **29** (2016) 045006 (8pp)

[2] Xinzhe Jin, Yasuteru Mawatari, Toshihiro Kuzuya, Yusuke Amakai, Yoshinori Tayu, Naoki Momono, Shinji Hirai, Yoshinori Yanagisawa, Hideaki Maeda, "Fabrication of 16-main-core RE123 split wire using inner split method," IEEE Transactions on Applied Superconductivity **29** (2019) 6601304 (4pp)

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Keywords: RE123, coated conductor, superconducting wire