WB Oral | Wires and Bulk

Thu. Dec 4, 2025 3:00 PM - 4:45 PM JST | Thu. Dec 4, 2025 6:00 AM - 7:45 AM UTC Room B(102)

[WB8] Evaluation & Flux Pinning II

Chair:Teresa Puig(ICMAB-CSIC), Satoshi Awaji(Tohoku University)

3:00 PM - 3:30 PM JST | 6:00 AM - 6:30 AM UTC

[WB8-01-INV]

Cryogenic irradiation of REBCO coated conductors for fusion magnets

*David X Fischer[1], Alexis R Devitre[1], Kevin B Woller[1], Ben C Clark[1], Zoe L Fisher[1], Zachery S Hartwig[1] (1. Massachusetts Institute of Technology (United States of America))

3:30 PM - 4:00 PM JST | 6:30 AM - 7:00 AM UTC

[WB8-03-INV]

TDGL Analysis of Flux Pinning in Coated Conductors: Effects of Pin Density and Strain Field Distribution

*Kaname Matsumoto Matsumoto[1,2], Tomoya Horide[2], Yutaka Yoshida[2] (1. Kyushu Inst. Tech. (Japan), 2. Nagoya Univ. (Japan))

4:00 PM - 4:30 PM JST | 7:00 AM - 7:30 AM UTC

[WB8-04-INV]

In-plane domain control of *RE*BCO coted conductors by applying bending strain and its effects on superconducting properties

*Tatsunori Okada[1,2], Daiki Hisatomi[1], Ryoma Kawamura[1], Itta Eshima[1], Kosei Ogawa[1], Yuhi Shimamura[2], Satoshi Awaji[2] (1. Kyushu Inst. of Tech. (Japan), 2. Tohoku Univ. (Japan))

4:30 PM - 4:45 PM JST | 7:30 AM - 7:45 AM UTC

[WB8-05]

Approach for EMP testing of thin REBCO tapes without burnout in cryogenic and high-magnetic field environments considering current flow direction and bridge geometry

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Cryogenic irradiation of REBCO coated conductors for fusion magnets

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Abstract

Fusion energy could contribution to the de-carbonization of the world's energy supply – if some major technological challenges can be overcome. Many stem from the nature of the deuterium-tritium reaction, the fusion process that requires the least extreme conditions of "only" 100 Mio K. It however creates a high energy neutron of 14 MeV that deteriorates many reactor components. This issue is exacerbated in compact high-field fusion devices because the higher neutron fluxes. These reactors require high-temperature superconducting fusion magnets, which are typically are designed to operate at 20 K and at fields of up to 20 T or more. Under these environmental condition radiation damage will be inflicted to magnet components like Rare Earth Barium Copper Oxide (REBCO) tapes.

To test the radiation resistance of REBCO tapes under fusion relevant conditions, we have commissioned an accelerator based cryogenic ion irradiation facility with in-situ transport current measurement capability [1].

With this setup, we irradiated REBCO tapes from two different manufacturers with 1.2 MeV to fluences of up to 10^{21} m^{-2} and found a significant influence of the irradiation temperature on the degradation of the superconducting parameters. Irradiations at 20 K degrade the critical current, n-value and transition temperature at a 1.6 times higher rate compared to irradiations at 300 K [2]. This has significant implications on how previous room temperature irradiation have to be evaluated regarding their fusion relevance.

Currently the ion irradiation facility is upgraded and a 14 T magnet is installed on the beam line. We hope to present at the conference the first ever cryogenic irradiation results of REBCO tape degradation measured in-situ and in high magnetic background fields. We further will give a status update on our cryogenic neutron irradiation facility that is currently under construction.

References

[1] Devitre *et al, Rev. Sci. Instrum*. **95**, 063907 (2024)

[2] Fischer et al, *SuST* **38** 055019 (2025)

Keywords: cryogenic irradiation, REBCO tapes, fusion magnets, in-situ measurements

TDGL Analysis of Flux Pinning in Coated Conductors: Effects of Pin Density and Strain Field Distribution

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Abstract

REBCO ($REBa_2Cu_3O_{7-\delta}$) coated conductors show excellent in-field critical current density (J_c) at low temperatures and high magnetic fields, making them key candidates for compact fusion devices and other high-field applications. Enhancing flux pinning through artificial pinning centers (APCs), such as nanorods, is effective; however, increasing APC density also introduces local strain, which can degrade T_c and J_c.[1,2] Thus, optimization requires a quantitative framework that incorporates both pin density and strain effects. In this study, we performed two-dimensional time-dependent Ginzburg–Landau (TDGL) simulations to analyze the dependence of the macroscopic pinning force F_p on nanorod density. Nanorods with diameters of 3–6 nm were introduced at volume fractions of 3–8 vol.% on a 400 × 100 grid, together with oxygen vacancies ($7-\delta = 6.93$) as shown in Fig.1. Without strain effects, simulations predicted a monotonic increase in F_p, reaching 3.7–3.8 TN/m³ at 6–8 vol.%, whereas experiments report an optimum near ~4 vol.% followed by rapid degradation. This discrepancy strongly suggests that strain fields play a decisive role in limiting performance at higher pin densities. To investigate this issue, we developed an original strain-distribution calculation method based on elasticity theory, capable of quantitatively visualizing local strain fields induced by nanorod introduction as shown in Fig.2. Although the full integration of this strain distribution into the TDGL framework is in progress, preliminary results indicate that overlapping strain fields at high APC concentrations can suppress the superconducting order parameter ψ and reduce the effective current paths, potentially accounting for the experimentally observed degradation. These findings suggest that the optimum pin density in REBCO conductors results from a trade-off between pinning enhancement and strain-induced limitations. The integration of TDGL simulations with elasticity-based strain modeling, once fully developed, is expected to provide a useful framework for guiding the design of next-generation REBCO coated conductors with improved flux pinning performance.

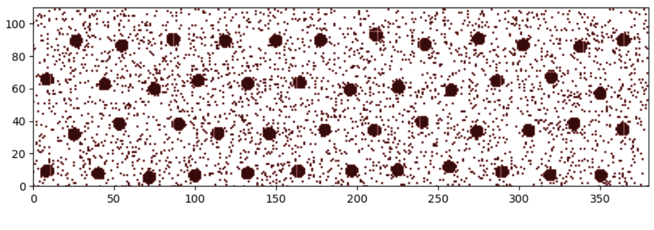

Fig.1 Distributions of nanorods and oxygen vacancies in REBCO thin films used for the TDGL simulations. Nanorod diameters were set to 3–6 nm, and their concentrations to 3–8 vol%.

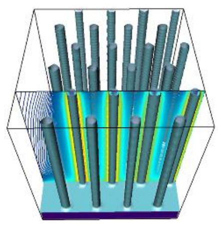

Fig.2 Visualization of strain fields induced by nanorod introduction into REBCO films using a newly developed strain-distribution calculation method.

References

[1] P. Mele, K. Matsumoto, *et al. Superconductor Science and Technology* 21 (2008) 125017.
[2] K. Matsumoto, *et al. Superconductor Science and Technology* 30 (2017) 104006.

Keywords: REBCO, coated conductor, flux pinning, TDGL, strain

In-plane domain control of *RE*BCO coted conductors by applying bending strain and its effects on superconducting properties

*Tatsunori Okada[1, 2], Daiki Hisatomi[1], Ryoma Kawamura[1], Itta Eshima[1], Kosei Ogawa[1], Yuhi Shimamura[2], and Satoshi Awaji[2]

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Abstract

In high-field magnet applications, *RE*BCO coated conductors (*RE*BCO CCs, *RE* is rare-earth elements) experience bending strain during a winding process and uniaxial tensile strain during its operation. Since *RE*BCO is an orthorhombic material, an in-plane twin structure comprised of two domains, “A-domain” and “B-domain”, where the *a*- and *b*-axis of *RE*BCO are respectively aligned in the direction of applied strain ε_a. It has been clarified that the critical temperature T_c of A- and B-domains exhibit almost opposite response to ε_a [1, 2], which likely underlies the complicated ε_a dependence of critical current density J_c under finite magnetic fields B [3]. To understand the complicated $J_c(\varepsilon_a, B)$ of *RE*BCO CCs, several attempts have been carried out to control the domain structure via *heat treatment* under compressive/tensile bending [4, 5] or uniaxial tension [2, 6]. Recently, we found that the domain fraction of *RE*BCO CCs can be modified simply by keeping *RE*BCO CCs bent at *room temperature* for a few days [5]. This means that the superconducting properties of *RE*BCO CCs wound into coils or cables may differ from those measured on straight short samples. Therefore, it is important to clarify how the bending-induced domain control influences on superconducting properties of *RE*BCO CCs.

In this study, we (i) controlled in-plane domain fraction of GdBCO CCs without artificial pinning centers (APCs) by applying tensile/compressive bending strain ε_b; (ii) qualified the domain fraction by x-ray diffraction; and (iii) performed DC transport measurements with $B \| ab \leq 15$ T [7]. Because the controlled domains tend to relax to their original state once the bending is released [5], experiments (ii) and (iii) were performed while keeping *RE*BCO CCs bent as in (i).

We confirmed that the A-domain fraction f_A, which was determined from the (200) and (020) reflections, varies linearly with ε_b as $f_A(\varepsilon_b) = (56 \pm 3) - (3.5 \pm 0.2) \times 10^3 \varepsilon_b$ [%] in $-0.45\% \leq \varepsilon_b \leq +0.45\%$, demonstrating that the domain structure of *RE*BCO CCs can be controlled within this bending-strain window (Fig. 1). T_c exhibits a “Λ”-shaped dependence on f_A with

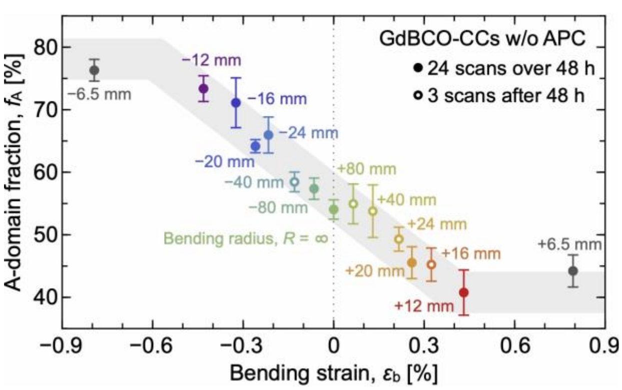

Fig. 1 A-domain fraction f_A of GdBCO CCs bent with a function of bending strain ε_b expected from jigs with bending radius R. The shaded curve is a guide to eyes. (after [7])

a maximum at $f_A \simeq 58\%$ ($\varepsilon_b \simeq -0.14\%$) (Fig. 2a), while the upper critical field $B_{c2}^{\|ab}$ exhibits a "N"-shaped, non-monotonic dependence on f_A (Fig. 2b). $J_c(f_A, B\|ab)$ measured at 77.3 K with increasing B shows a crossover from an "N"-shaped to a "V"-shaped f_A dependence at around 4 T (Figs. 2c and 2d). This crossover in $J_c(f_A, B\|ab)$ suggests the change in the dominant vortex-pinning mechanism in high- and low-f_A samples (i.e., compressive- and tensile-bent *RE*BCO CCs). Fig. 2 demonstrates that there is a possibility that in-field quantities become superior to those of the as-received sample, but further investigations are necessary to understand those behaviors.

At the symposium, we would like to present these results in detail and, if possible, report on-going investigations on domain control in *RE*BCO CCs with different APCs.

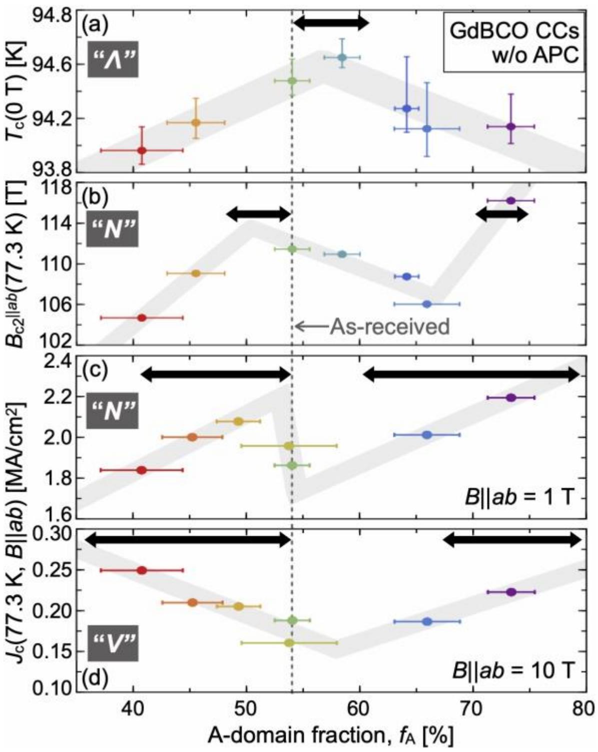

Fig. 2 A-domain fraction dependence of critical temperature T_c (a), upper critical field $B_{c2}^{\|ab}$ at 77. 3 K (b), critical current density J_c at 77.3 K (c) and (d) of domain-controlled GdBCO CCs. The shaded curves are guides to eyes, and the black arrows indicate f_A range in which quantities become superior to those of the as-received CC. (after [7])

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Acknowledgements

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Keywaords: REBCO coated conductors, domain control, bending strain, transport properties

Approach for EMP testing of thin REBCO tapes without burnout in cryogenic and high-magnetic field environments considering current flow direction and bridge geometry

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The reliable operation of REBCO coated conductors in high-field devices for fusion, NMR, and accelerators is critically dependent on their electromechanical properties (EMP). This study discusses approaches for enabling critical current (I_c) (B, 20 K) and electromechanical properties I_c (B, T, ε/σ) testing under tensile load on thin standoff REBCO samples at high magnetic fields and cryogenic temperatures (20 K) without the common issue of sample burnout. A key challenge is the Lorentz force, which, acting on an unsupported tape, induces significant transverse stress, leading to in-plane bending, out-of plane deflection and premature delamination at striation-induced bridges. This can cause irreversible I_c degradation or quench. To mitigate this, we explore the directional dependence of Lorentz force against the bridge pattern by systematically controlling the force direction, we demonstrate a mechanism, preventing the detrimental buckling observed in conventional test setups. Our approach for EMP experiments shows that a strategically reversed force direction can shift mechanical stress away from critical regions, preventing burnout. Furthermore, we highlight the imperative of addressing transverse electromagnetic stress from screening currents, a hidden degradation mechanism. Preliminary modeling indicates that these forces can generate localized stresses during field ramping, potentially explaining premature delamination observed in experiments. Our work provides a clear roadmap for designing more resilient REBCO tapes and optimizing striation patterns for bridges by exploiting directional Lorentz to enhance a conductor's mechanical integrity in extreme electromagnetic environments at cryogenic temperatures.

Keywords: Thin substrate REBCO tapes, High field-current, Lorentz force, Tape's bridging, Electromechanical properties (EMP)