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Strain Characteristics of I_c in Brass Laminated CC tapes under Tension at Various Low Temperature and Magnetic Field Conditions

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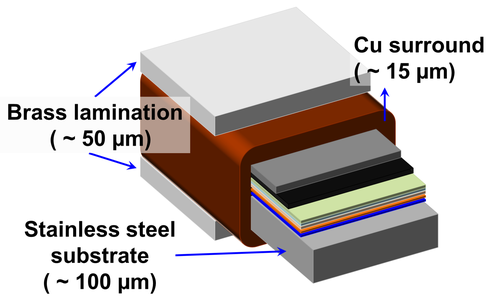
Introduction

- The applications of CC tapes to the high-field magnet still require further improvement of their mechanical and electromechanical properties in order to achieve significant upgrades.
- The effect of magnetic field, *B* on the I_c degradation behavior of CC tapes varies depending on its orientation with respect to the surface. Also, the operating temperature, *T*, varies the designed transport limit of CC tapes for each application.
- Therefore, in the design and the construction of magnets and coil applications, it is important to evaluate the transport property of CC tapes with different CC tape configuration under various *B*, and *T*. Because straining of CC tapes beyond its critical limit surely leads to damage such as cracks and resultantly failure of the device.
- Therefore, it is meaningful to further investigate the influence of its laminate configuration on the electromechanical properties to optimize the CC tape's performance.
- In this study, further investigations of strain/stress characteristics of the I_c in the laminated GdBCO CC tapes were conducted under various temperature and magnetic field conditions, I_c (*B*, *T*, and ε). The differently determined irreversible strain/stress limits were compared.

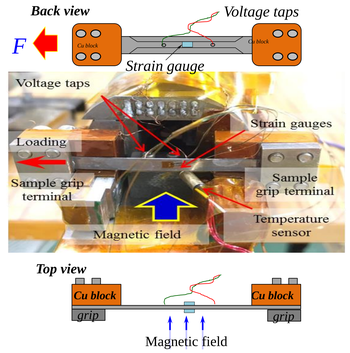
Experimental procedure

Sample configurations and specifications



Fabrication process	IBAD-RCEDR
Structure	Ag/GdBCO/$LaMnO_3$/ IBAD MgO/ Y_2O_3/Al_2O_3/ Substrate (stainless steel)
REBCO film *t*	~ 1 μm
I_c @ 77 K & *s.f.*	~ 205 A
Dimension, *t* x *w*	0.240 mm x 4.13 mm
Substrate, *t*	Stainless steel, ~100 μm
Stabilizer/technique, *t*	Cu stabilizer, ~15 μm
External lamination, *t*	Brass solder lamination, ~50 μm
Manufacturer	SuNAM

Set-up for uniaxial tension test



Schematics of CC tape sample mounted onto the tensile loading rig showing different views with strain gauges.

- The electromechanical properties of the brass-laminated CC tape samples under different *T* and *B* conditions were evaluated using the Katagiri-type probe available at the HFLSM, IMR at Tohoku University, Japan.
- In the sample position, the external magnetic field using the 10 T cryocooler superconducting magnet was applied to *B*//*c*-axis of CC tape.
- Total length of sample was 60 mm.
- For the I_c measurement at lower temperature:
  - ~2 mm width and 20 mm long bridge striated on the CC tape sample to ensure that it does not exceed the capacity of the 200 A power supply during tested at lower temperature.
  - Voltage taps separation :10 mm
  - I_c was measured using the four-probe method with an electron-field criterion of 1 μV/cm

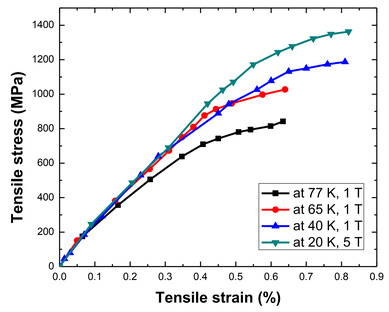
Criteria of irreversible strain/stress limits determination by unloading to 20 N,

1. a 99% I_c- *recovery* or 1% deviation from the loading curve upon unloading.
2. a 95% I_{c0} retention during loading.

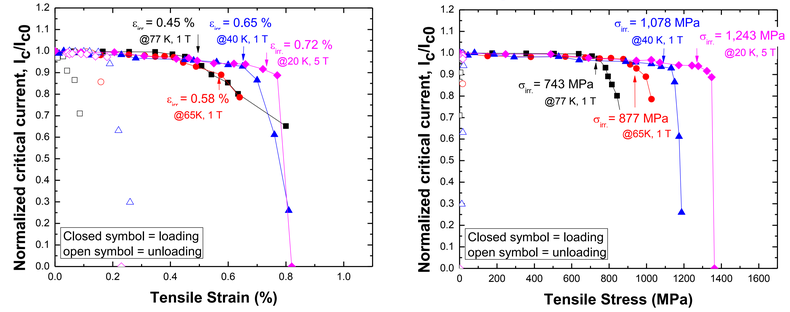
Results and Discussion

Mechanical and electromechanical properties of brass laminated GfBCO CC tapes

Stress-strain curves



Strain / Stress sensitivity of I_c



Conditions (T, B)	E (GPa)	σ_y (MPa)	*99% Ic recovery* $\varepsilon_{irr.}$ (%)	*99% Ic recovery* $\sigma_{irr.}$ (MPa)	*95% I_c retention* $\varepsilon_{irr.}$ (%)	*95% I_c retention* $\sigma_{irr.}$ (MPa)
77 K, 1 T	193	752	0.45	743	0.45	743
65 K, 1 T	194	979	0.58	877	0.44	877
40 K, 1 T	221	1 169	0.65	1 078	0.48	942
20 K, 5 T	220	1 323	0.72	1 243	0.49	1 071

- In the stress-strain curves, the increase of its yield strength with decreasing temperature was observed even there is an applied external magnetic field. This behavior was already known as resulted from low temperature hardening effect at low temperature.
- An increase of the irreversible strain limit in the brass laminated CC tapes was observed as the temperature decreased from 77 K to 20 K. Also it can be found that REC-DR CC tapes showed a significant strain tolerance of I_c at low temperature conditions.
- It can be found that the increase of the irreversible stress limit , $\sigma_{irr.}$, was also observed during the decrease of temperature from 77 K to 20 K with the increase of its yield strength.
- The irreversible strain limits were significant increased when determined by the 99 % I_c recovery criterion from 0.45% for 77 K to 0.72% for 20 K which are different from the case determined by 95 % I_{c0} retention criterion which showed a minimal increase from 0.45% to 0.49%.
- For irreversible stress limits, it showed similar behavior of stress values for both criterions. As further decrease of temperature, there existed some difference. but it was still increased with lower temperature in the comparison of both criterions.

Conclusions

- The strain/stress characteristics of I_c in brass laminated GdBCO CC tapes at various temperature and magnetic field conditions were investigated.
- For the mechanical property, the yield strength increased with decreasing test temperature due to the low temperature hardening effect even there is an applied external magnetic field. Such increased yield strength resulted to the increasing of ε_{irr} and $\sigma_{irr.}$ limits as well as the decreasing strain sensitivity of I_c at low temperature conditions.
- The strain tolerance so as the critical strain limit of the RCE-DR processed GdBCO CC tapes showed significant enhancement with decreasing temperature condition but was not clearly affected by the magnetic field.
- In the comparison of both criteria, it shows that the 99% I_c-ε recovery showed a higher value with a large of irreversible limits in both stress and strain limits as the temperature decreased which was different from the case of the 95% I_{c0} retention.

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