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Performance Evaluation of Practical REBCO Coated Conductor Tapes for Superconducting Wind Power Coils

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Introduction

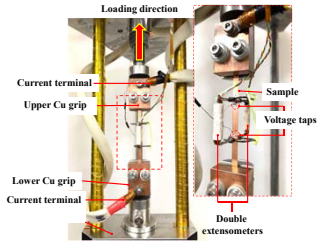
- Large-scale applications of REBCO coated conductor (CC) tapes, particularly in superconducting wind turbine generators, must encompass high power generation efficiencies and low-weight designs; they can do so by utilizing the REBCO CC tapes with high performance at cryogenic temperatures and under magnetic fields.
- Performance evaluations of the CC tapes are carried out by investigating the dependency of I_c on stress and strain, including the irreversible I_c degradation region under an external magnetic field.
- In this study, electromechanical properties such as I_c degradation behavior and its irreversible strain/stress limits of three commercially available REBCO CC tapes were examined using uniaxial tension tests at the expected CC coils operating conditions, 35 K and 2 T. Results were also compared to those obtained at 77 K and self-field.

Experimental procedure

Sample specifications

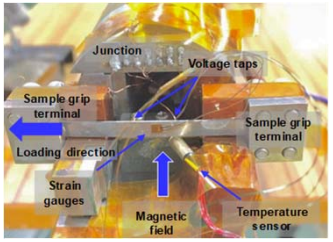
Fabrication process	IBAD/RCE-DR	ISD/RCE	IBAD/MOCVD
Type	Cu-stabilized	Ag-stabilized	Cu-stabilized
Structure	Ag/GdBCO/ $LaMnO_3$/ Homo-epi MgO/ IBAD-MgO/ Y_2O_3/ AlO_3/Stainless steel	Ag/GdBCO/ MgO/Hastelloy	Ag/YBCO/LaMO/ Homo-epi MgO/IBAD-MgO/Hastelloy
REBCO film thickness	~ 1.5 μm	~ 3-5 μm	~ 1.6 μm
Critical current, I_c @ 77 K	~ 245 A	~ 250 A	~ 111 A
Dimension, t x w (mm)	0.131 x 4.04	0.099 x 4.02	0.085 x 4.05
Substrate/ thickness	Stainless steel/ ~100 μm	Hastelloy/ ~50 μm	Hastelloy/ ~50 μm
Stabilizer/ thickness	Cu electroplated/ (~15 μm)	Ag-electroplated (~5 μm)	Cu electroplated/ (~15 μm)

Uniaxial tension test setup for electro-mechanical properties measurement at 77 K and self-field



- ✓ Voltage tap separation: 20 mm
- ✓ I_c was measured at an electric field criterion of 1 μV/cm in 0.05% strain interval

Set-up for I_c measurement of CC tapes during uniaxial tension at 35 K and 2 T

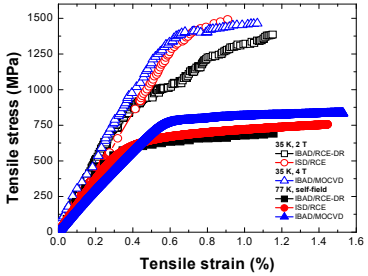


- ✓ The CC tape sample was mounted to the bottom part of the test rig probe.
- ✓ The external magnetic field coming from the 10-T cryocooled superconducting magnet was directed to the B//c-axis of CC tape sample.
- ✓ ~2 mm wide and 20 mm long bridge was fabricated on the center of the CC tape for I_c measurement at 35 K.
- ✓ Voltage tap separation: 10 mm

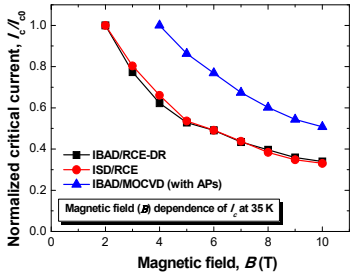
Characterization of the CC tape samples was conducted using the Katagiri-type tension rig in the High Field Laboratory for Superconducting Materials, Institute for Materials Research, Tohoku University

Results and Discussion

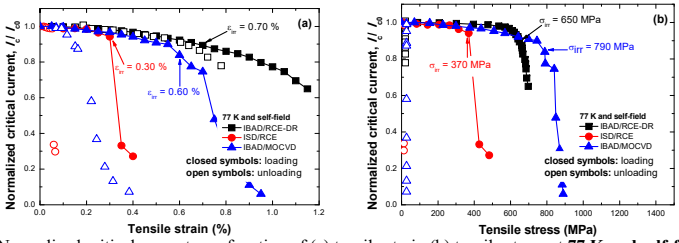
Mechanical properties of REBCO CC tapes at cryogenic temperatures



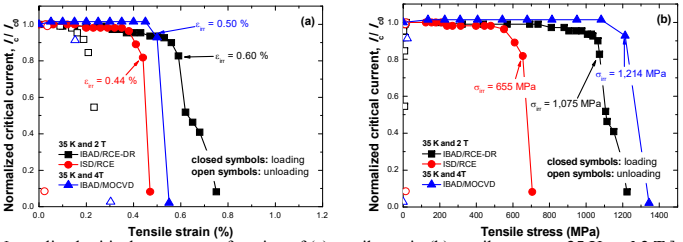
Magnetic field dependence of I_c/I_{c0} of REBCO CC tape samples at 35 K (at unstrained state).



Electromechanical properties of REBCO CC tapes at various test conditions



[Normalized critical current as a function of (a) tensile strain (b) tensile stress at **77 K and self-field**.]



[Normalized critical current as a function of (a) tensile strain (b) tensile stress at **35 K and 2 T**.]

Electromechanical properties of commercially available REBCO CC tapes at various test conditions.

CC tape Sample	Critical current, I_c (A)	Elastic modulus, E (GPa)	Yield strength, σ_y (MPa)	Irreversible strain limit, $\varepsilon_{irr.}$ (%)	Irreversible stress limit, $\sigma_{irr.}$ (MPa)	Critical current, I_c (A)	Elastic modulus, E (GPa)	Yield strength, σ_y (MPa)	Irreversible strain limit, $\varepsilon_{irr.}$ (%)	Irreversible stress limit, $\sigma_{irr.}$ (MPa)
	77 K and 0 T					35 K and 2 T				
IBAD/RCE-DR	245	189	682	0.70	650	55 *	234	1,046	0.60	1,075
ISD/RCE	234	153	944	0.30 #	370 #	112 *	207	1,493	0.44	655
						35 K and 4 T				
IBAD/MOCVD	110	156	782	0.60	790	138	226	1,420	0.50 #	1,214 #

* I_c was measured at 2mm width bridge introduced on the 4 mm CC tapes. # 95% I_{c0} retention criterion was used. ($\varepsilon_{ret.}$, $\sigma_{ret.}$)

Conclusions

- All samples showed a significant increase in elastic modulus, yield strength, and irreversible stress limit, due to the hardening effect at low-temperatures.
- RCE-DR CC tapes showed superior irreversible strain limit at 35 K and 2 T, and MOCVD CC tape exhibited the greatest irreversible stress limit at 35 K and 4 T.
- ISD/RCE CC tape showed a behavior that the irreversible limit values enhanced as test conditions were changed from 77 K and a self-field to 35 K and 2 T.
- All practical CC tape samples exhibited critical values exceeding the irreversible strain/stress limits required for offshore wind power coil applications.

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