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Electromechanical Properties Evaluation of Multifilamentary MgB_2 Wires with Different Reinforcements

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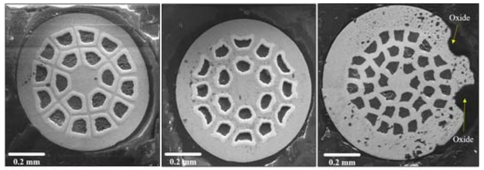
Introduction

- ❑ Magnesium diboride (MgB_2) wires are highly attractive for various device applications, due to advantages during fabrication, given their high critical transition temperatures.
- ❑ The strong reinforcing material adaption increases the density of MgB_2 filaments and enhances their grain connectivity, eventually enhancing their stress tolerance rendering them promising alternatives to HTS wires.
- ❑ The strength of the metallic sheath is not the only determinant of the high irreversible strain/stress limits; filament quality (grain connectivity) which results from the various powders (ex-situ, in situ, and mechanically alloyed) also plays an important role.
- ❑ The aim of this contribution is to present and compare the mechanical and electromechanical behaviors of differently fabricated filamentary MgB_2 wires with various metallic reinforcements by uniaxial tension tests at the condition of 20 K and 2 T.

Experimental procedure

❑ Sample specifications



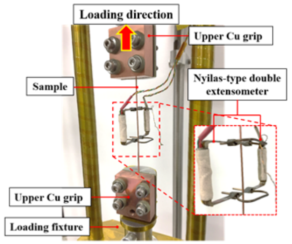
(a) (b) (c)

✓ Cross-sectional images of the MgB_2 wires: (a) Sample 1, (b) Sample 2, and (c) Sample 3.

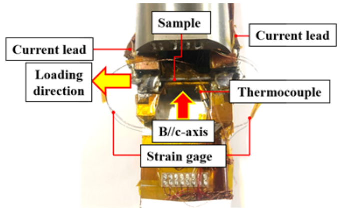
MgB_2 wire parameter	Sample 1	Sample 2	Sample 3
No. of filaments	18	18(+1)	36
Wire diameter (mm)	1.03	0.80	1.3
Filament material		MgB_2	
Barrier material	Nb	-	-
Sheath matrix	Monel	SUS	Iron
Additional treatment	HIP (600 °C, 1 hr)	-	-
I_c (A) at 20 K, 2 T	73	69	41

- The mechanical properties of the MgB_2 wires were obtained at 77 K using samples having 120 mm in total length and 60 mm in gauge length.
- At 20 K under magnetic fields, the Katagiri-type tension test rig was used to evaluate the electro-mechanical properties of the MgB_2 wires.
- The 10 T superconducting magnet at HFLSM, IMR, Tohoku University was used in this study.

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



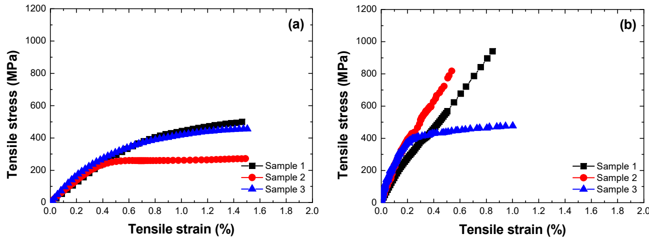
❑ Set-up for I_c measurement of MgB_2 wires during uniaxial tension at 20 K and 2 T



✓ Voltage tap separation: 10 mm

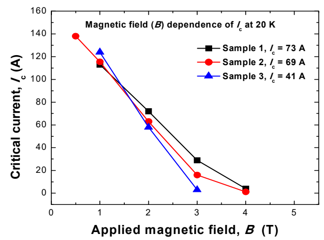
Results and Discussion

❑ Mechanical properties of differently reinforced multifilamentary MgB_2 wires at cryogenic temperatures



✓ Stress-strain curves of various MgB_2 wire samples at (a) 77 K, 0 T and (b) 20 K, 2 T.

❑ Magnetic field dependence of I_c in various multifilamentary MgB_2 wires at 20 K.

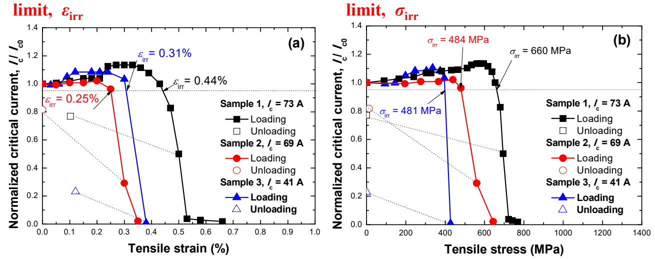


✓ I_c decreased significantly as the applied B increased regardless of the metallic reinforcing material or additional treatment.

❑ Electromechanical properties of differently reinforced MgB_2 wires at 20 K and 2 T

$I_c(\varepsilon)$ behaviors and Irreversible strain limit, ε_{irr}

$I_c(\varepsilon)$ behaviors and Irreversible stress limit, σ_{irr}



❑ Mechanical and electromechanical properties of various MgB_2 wires obtained.

Sample No.	Mechanical properties: Elastic modulus, E (GPa)	Mechanical properties: Yield strength, σ_y (MPa)	Mechanical properties: Elastic modulus, E (GPa)	Mechanical properties: Yield strength, σ_y (MPa)	Electromechanical properties: Irreversible strain limit, $\varepsilon_{irr.}$ (%)	Electromechanical properties: Irreversible stress limit, $\sigma_{irr.}$ (MPa)	Electromechanical properties: Strain at I_c peak, ε_{Icpeak} (%)
	77 K, 0 T		20 K, 2 T		20 K, 2 T		
1	64	417	142	941	0.44	660	0.33
2	92	333	172	885	0.25	484	0.20
3	74	250	178	513	0.31	481	0.24

✓ As the test temperature decreased from 77 K to 20 K, all samples exhibited a significant increase in σ_y and E due to low-temperature induced hardening.

✓ All MgB_2 samples exhibited an I_c peak, showing a behavior that I_c increased gradually with the applied tensile strain. Sample 1 exhibited the greatest I_c peak and irreversible strain limit. Once the peak was reached, then I_c decreased significantly with further increase of applied strain and did not show a complete recovery of I_c once returned to the unloaded state.

✓ At 20 K and 2 T, all MgB_2 wire samples showed much lower σ_{irr} as compared to its σ_y. σ_{irr} was significantly influenced depending on the metallic sheath adopted.

Conclusions

- ❑ All tested MgB_2 wires exhibited a significant increase in yield strength when the test temperature decreased from 77 K to 20 K, the result of a low-temperature hardening effect.
- ❑ At 20 K, MgB_2 wires exhibited similar $I_c(B)$ behaviors, regardless of sample configuration and reinforcement.
- ❑ Reinforcing MgB_2 wires with strong sheath materials and adopting additional treatments such as HIP could enhance the irreversible strain and stress limits for I_c degradation.

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