Properties of Critical Current and Normal Zone Propagation of Multi-filamentary MgB2 Superconducting Wire Cooled by Liquid Hydrogen

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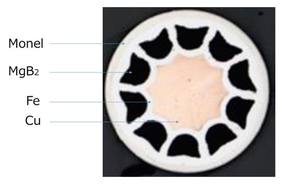
1.INTRODUCTION

- Liquid hydrogen is expected to be used as a new coolant for the high *Tc* superconductor due to large latent heat, low viscosity coefficient.
  Our purpose is to develop applications of **superconductivity cooled by LH_2**.

	T_{sat} [K]	ρ_l [kg/m^3]	μ_l [μPa · s]	h_{fg} [kJ/kg]	c_p [kJ/kg · K]
WATER	373.15	960.59	291.4	2257	4.212
NITROGEN	77.35	808.6	177	198.6	2.071
HYDROGEN	20.39	70.79	12	443	10.2
HELIUM	4.22	125	3.182	20.4	4.88

- **MgB_2** is chosen from among the HTS
  MgB_2 is expected to be applied to various superconducting devices due to the low cost fabrication and the high critical temperature that is about 40K.

- MgB_2 is suitable to be cooled by LH_2
  The boiling temperature of LH_2 is 20.4K, so the temperature margin is sufficient to ensure cooling stability. we used **10-filament** MgB_2 superconducting wire.



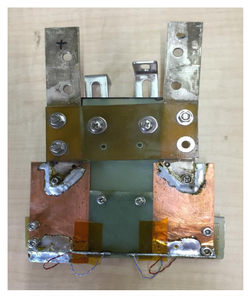
- The dependence of the I_c on the temperature and the magnetic field was measured. we estimated *V-I* property of the MgB_2 wire **under the magnetic field**.

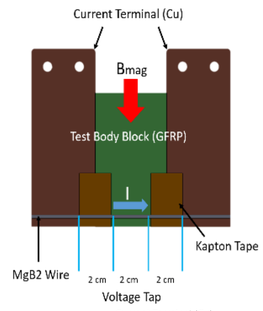
- **The normal zone propagation** of the MgB_2 wire was observed
  It is important to understand quantitatively how the quench happens under the condition that the MgB_2 wire is cooled by LH_2. Therefore, we measured normal zone propagation velocity (NZPV) and the minimum quench energy (MQE).

2.Experimental apparatus and setup

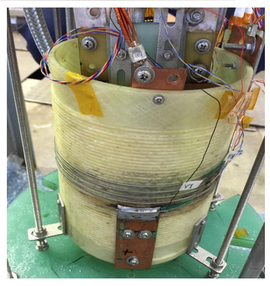
Test sample

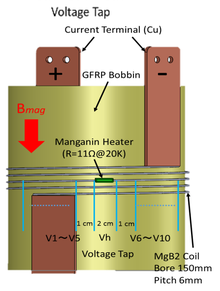
- **MgB_2 short sample**
  Diameter: 1.5 mm
  MgB_2/Cu/Fe/Monel=0.24/0.21/0.40/0.15
  Length: 100 mm
  Voltage taps: 20 mm

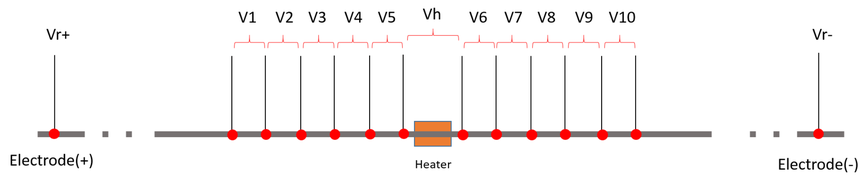




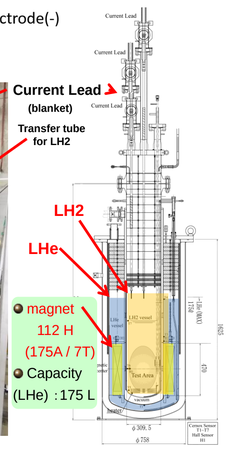
- **MgB_2 coil sample**
  The same MgB_2 wire as the short sample
  length: 200 cm
  Diameter of the bobbin: 15 cm
  Voltage taps: 10 mm × 10
  Manganin heater is set on the MgB_2 wire







Test LH_2 cryostat
Diameter: 309.5 mm inner
Height: 2122 mm
LH_2 temperature: 21-30 K
Magnetic field: 0-7.0 T
(by Nb-Ti superconducting magnet cooled by LHe)



3.Experimental procedure

Critical Current Property Test

- The test was carried out in the state that the MgB_2 wire was immersed in LH_2.
- The bulk-liquid temperature was set to 21-30 K by use of the sheath heater.
- The pressure in the LH_2 cryostat was set to saturated condition.
- The magnetic field was set to 0-6.0 T by use of the Nb-Ti superconducting magnet cooled by LHe.
- Electrical current applied to the MgB_2 wire was controlled to increase linearly, and shut off automatically to avoid burn-out.
- The tap voltages were measured by the four-terminal sensing method.

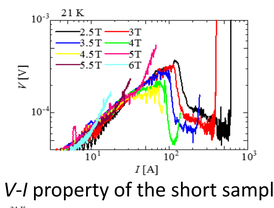
Normal Zone Propagation Property Test

- The experiment was carried out in the state that the MgB_2 wire was immersed in LH_2.
- The bulk-liquid temperature is comparatively high, and the magnetic field is comparatively small, for making the MgB_2 superconductivity fragile.
- The MgB_2 wire is applied constant transport electrical current (I_t<I_c).
- The Manganin heater is momentarily applied electrical current and generates heat.
- By the heat, the superconductivity of the MgB_2 is broken and generates joule heat itself, and normal zone propagates in chains.
- The run of events was observed by measuring the 10 voltage taps around the Manganin heater.

4.Result and Discussion

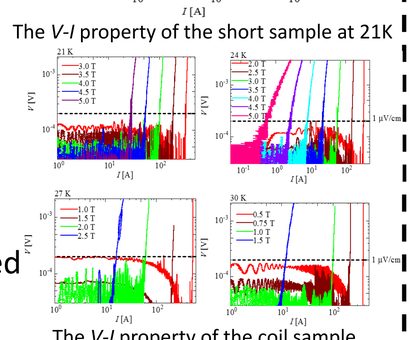
The critical current property

- The *V-I* property of the short sample was unclear because the noise level was great.

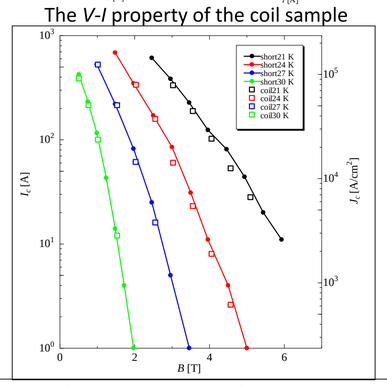


The *V-I* property of the short sample at 21K

- Instead of it, the coil sample was measured.
  The voltage tap measured the entire voltage of the 200cm MgB_2 , so the critical current was determined at the point that the tap voltage reached 200 μV.



The *V-I* property of the coil sample

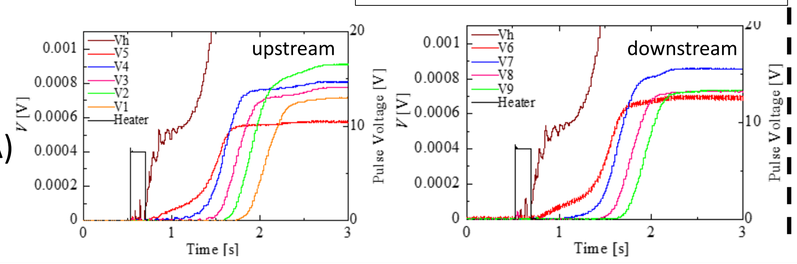


The critical current and critical current density at each temperature

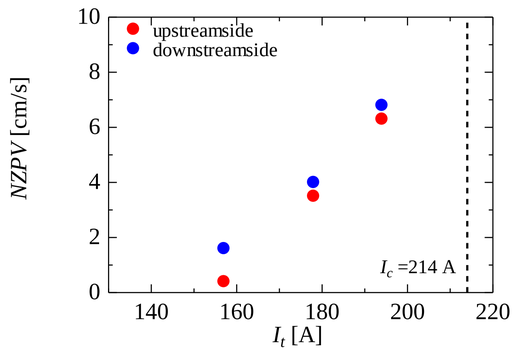
The normal zone propagation property

- The normal zone propagation could be measured at the only 3 conditions.
  (T, B, I_t)=(30K, 0.75T, 194A), (30K, 0.75T, 178A), (30K, 0.75T, 157A),
  *I_c = 214 A at (T, B)=(30K, 0.75T)

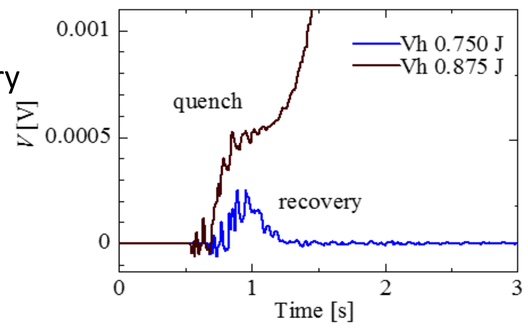
- The right figure is the result of the condition (T, B, I_t)=(30K, 0.75T, 194A)



Normal zone propagation velocity (NZPV)
NZPV was calculated at each I_t.
NZPV is in the order of cm/sec,
and increases as I_t increases.



Minum Quench Energy (MQE)
Right figure shows the patterns of quench and recovery at the condition (T, B, I_t) = (30 K, 0.75 T, 194A).
In this case, MQE is determined 0.875 J.
In the same way, MQE is
1.25 J at (T, B, I_t) = (30K, 0.75T, 178A),
2.75 J at (T, B, I_t) = (30K, 0.75T, 157A).



5.Conclusion

- The critical current of the mulch-filamentary MgB_2 immersed in liquid hydrogen (21-30 K) was measured under magnetic field (0-6 T).
- The normal zone propagation of the MgB_2 wire immersed in liquid hydrogen could be observed at some conditions. It is determined that NZPV is in the order of cm/sec, and the MQE is in the order of Joule.