Influence of High Thermal Conductivity Plastic with Negative Thermal Expansion Coefficent on Cooling Performance in Conduction Cooled HTS Coils

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MOTIVATION

IHCP: Insulative Heat Conduction Plastic

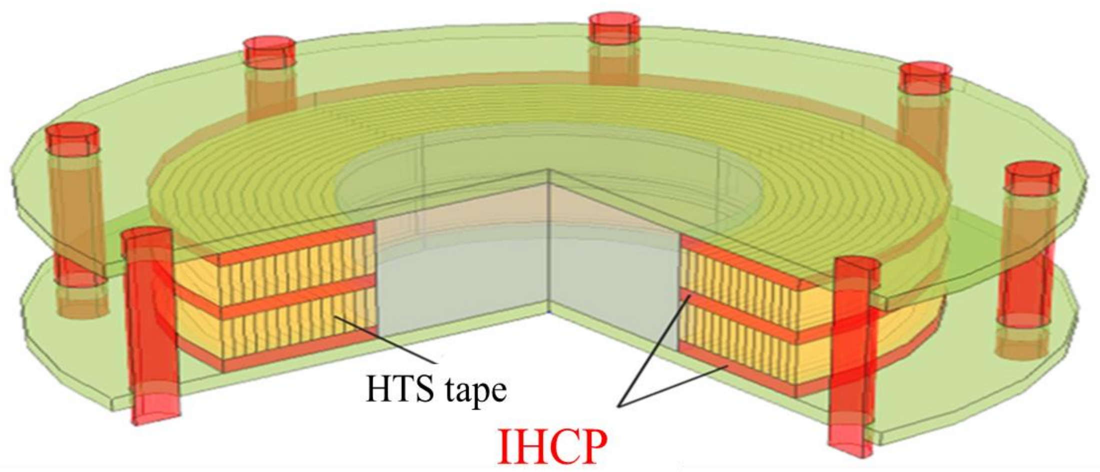
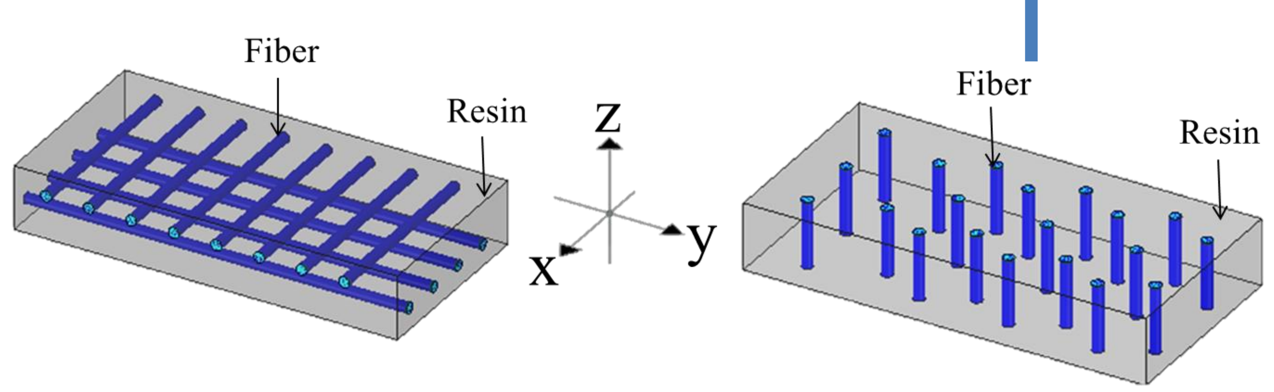


Fig. 1. Application example of the IHCP.



(a) Previous FRP (b) IHCP

Fig. 2. Fiber directions in FRPs: (a) parallel and (b) perpendicular.

The IHCP is effective for increasing the thermal stability of a HTS coil.

THERMAL CONDUCTIVITY MEASUREMENT

・Thermal conductivity was estimated from thermal gradient.

Thermal conductivity is given by

$$\lambda = \frac{LQ}{S(T_1 - T_2)}$$

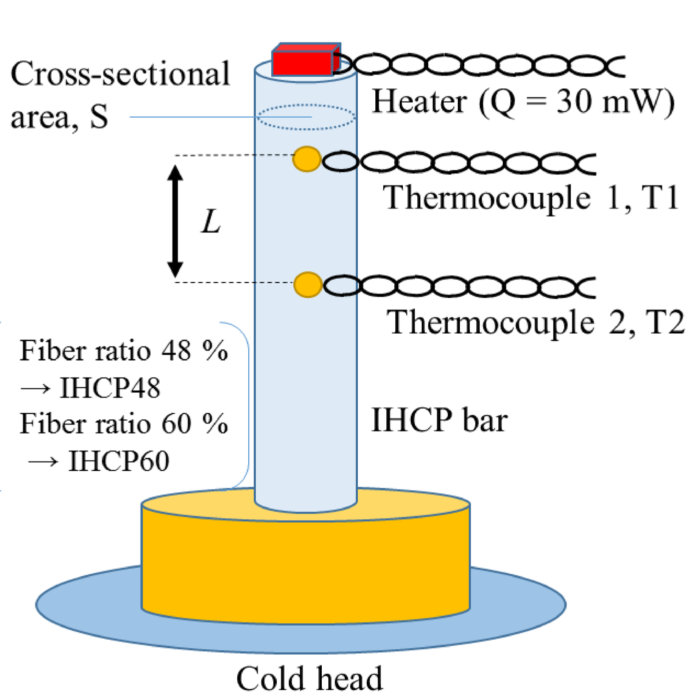


Fig. 3. Experimental setup for thermal conductivity measurements.

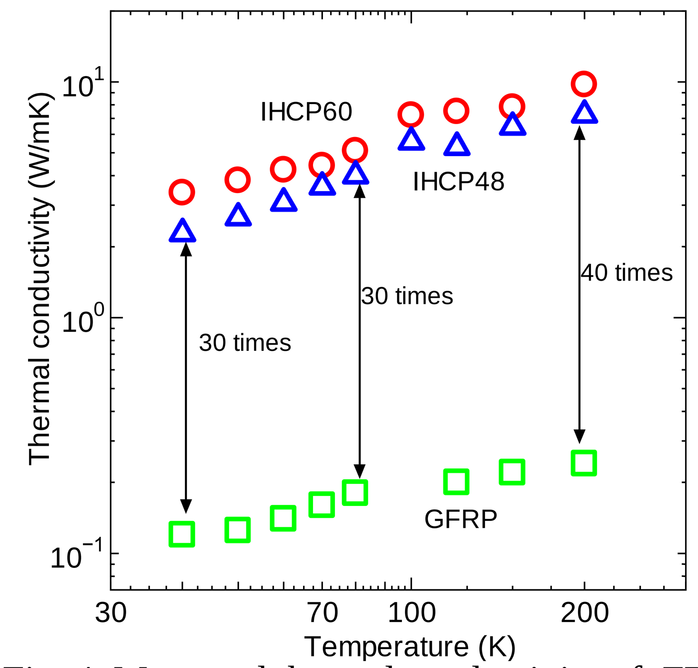
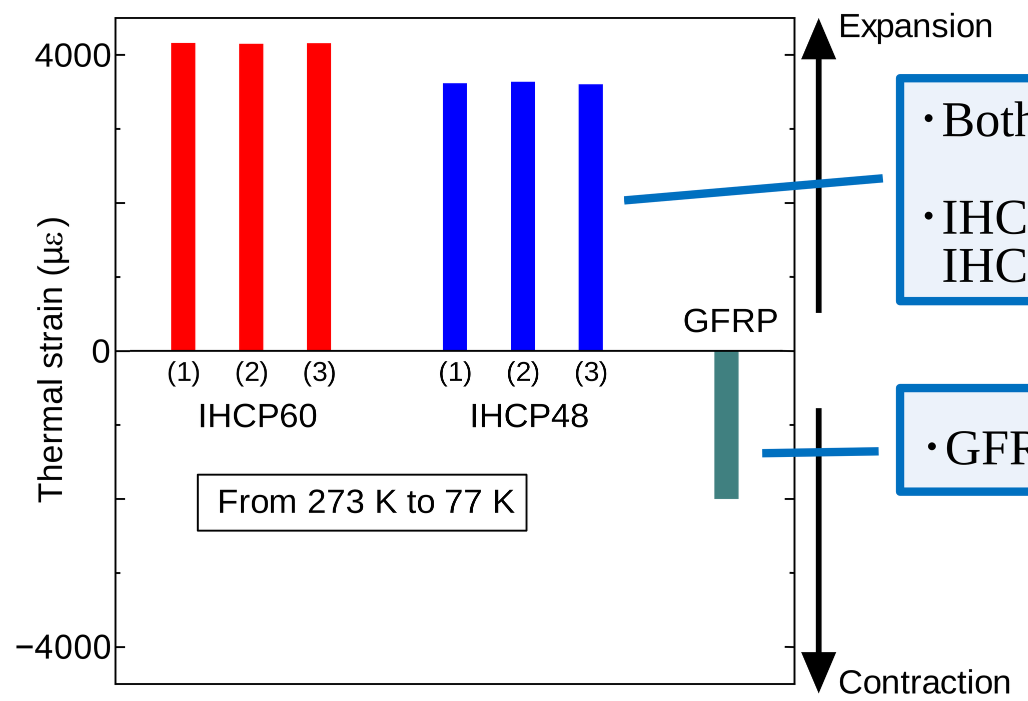


Fig. 4. Measured thermal conductivity of FRPs.

THERMAL STRAIN MEASUREMENT

・The same FRP round bar was used as the thermal conductivity measurements.

・To confirm the measurements, they were performed three times.



・Both of IHCP bar expanded.

・IHCP60's strain was larger than IHCP48's strain.

・GFRP bar contracted

Fig. 5. Measured thermal strains for FRPs.

HEATER QUENCH TEST

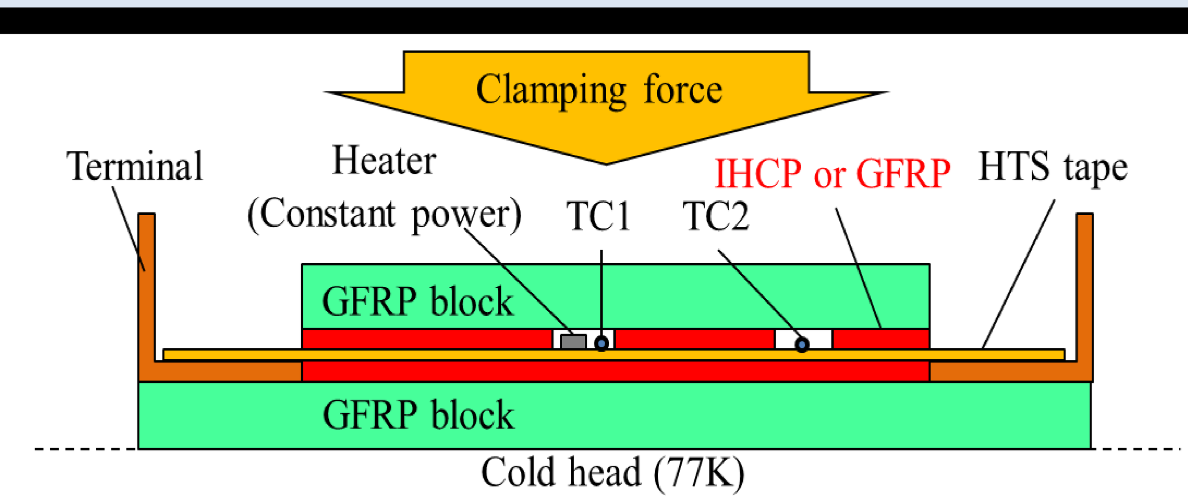


Fig. 6. Experimental setup for the heater quench test.

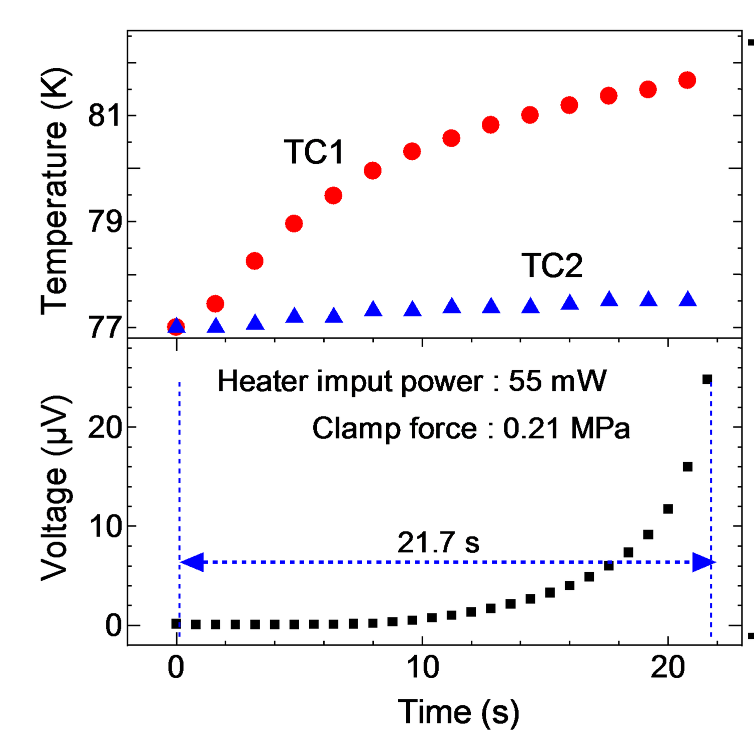


Fig. 7. Typical measured waveforms for FRP temperature (top) and voltage (bottom).

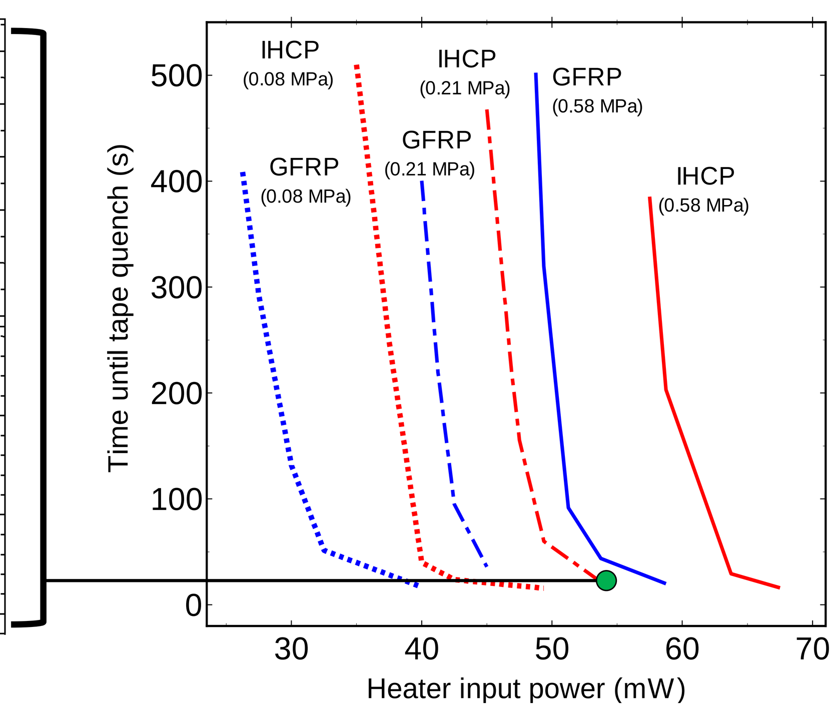


Fig. 8. Relationship among heater input power, clamping pressure, and time until quenching.

・Quench time with the IHCP is longer than that with the GFRP.

Cooling with the IHCP is effective.

ESTIMATION OF CONTACT THERMAL RESISTANCE

・Experimental setup shown in Fig. 5. was simulated by COMSOL Multiphysics®.

・The quench tests using the local heater as described in the previous section was numerically analyzed.

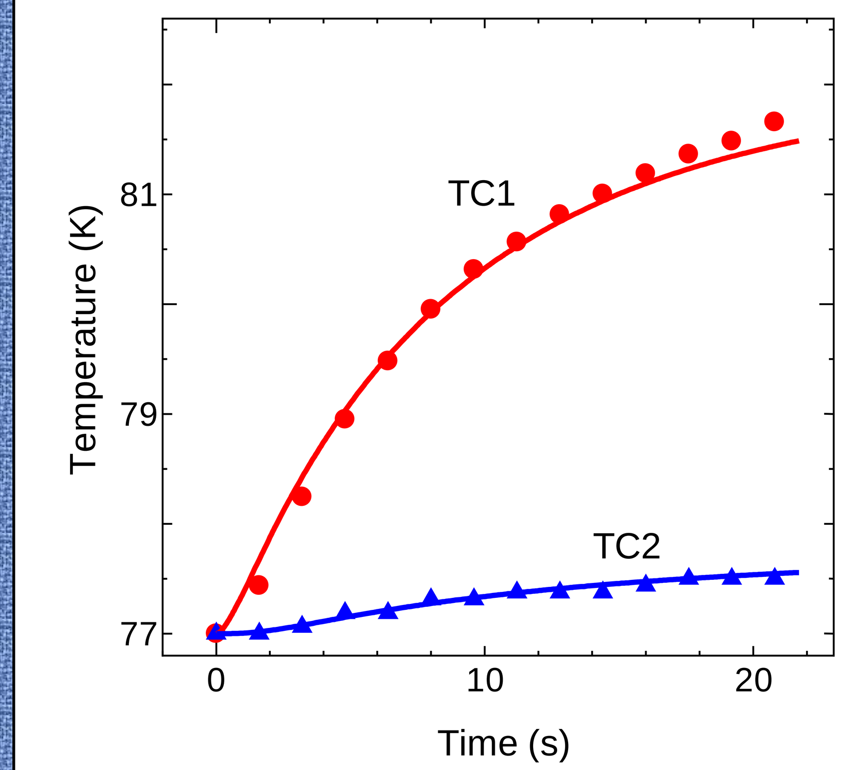


Fig. 9. Typical measured waveforms for FRP temperature.

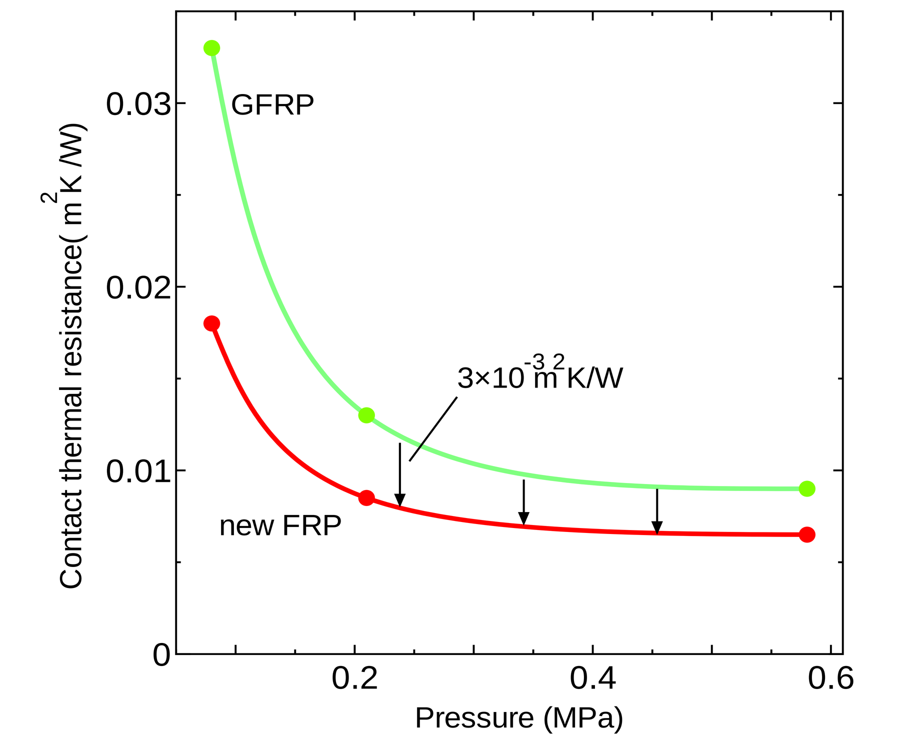


Fig. 10. Dependence of contact thermal resistance on contact pressure.

・The temperature simulation data seems to agree well with the measured.

Low contact thermal resistance because of expansion coefficient.

SUMMARY

High thermal conductivity
× 30
GFRP → IHCP

Expansion with cooling
→ IHCP : 4000 με

Low contact thermal resistance
3 × 10^{-3} m^2 K/W

Time until HTS tape quenching with IHCP became longer.
GFRP : 20 s → IHCP : 203 s (60 mW , 0.58 MPa)

The IHCP is effective for increasing the thermal stability of the HTS coil.