PB-26

Thermal conductance and high frequency properties of cryogenic normal or superconcuting semi-rigid coaxial cables in a range of 1 and 8 K

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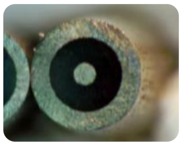
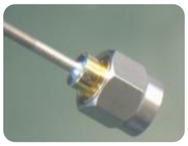
The semi-rigid cable is a kind of coaxial cable with seamless outer electrical conductor shielding center conductor through dielectric.
We have developed some types of thin semi-rigid coaxial cables for low temperature experiments, and report performances of ϕ0.86 mm samples.

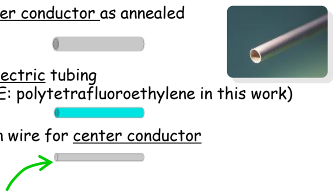
- low thermal conductance and moderate attenuation by normal metals with relatively low cost
- low thermal conductance and quite small attenuation employing superconductors



Semi-rigid coaxial cables –preparation-

- outer conductor as annealed
- dielectric tubing (PTFE: polytetrafluoroethylene in this work)
- thin wire for center conductor



drawing with dies & lubricant oil
⇓
aging to release stress in PTFE
⇓

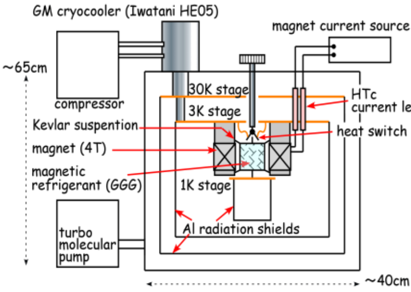
※silver plating on normal center conductor when reduction of attenuation is needed

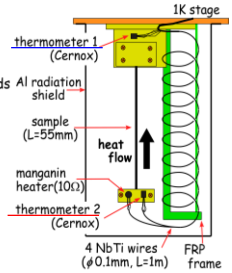
Samples for evaluation

Sample name (center – outer)	Center conductor outer diameter: 0.20mm	Cuter conductor outer diameter: 0.86mm
BeCu - BeCu	BeCu (beryllium- copper)	BeCu
brass- brass	brass	brass
CuNi - CuNi	CuNi (cupro-nickel)	CuNi
SUS - SUS	SUS304 (stainless-steel)	SUS304
CuNi (Ag) – CuNi	silver (3μm thickness) plating CuNi	CuNi
SUS (Ag) -SUS	silver (3μm thickness) plating SUS304	SUS304
Nb - Nb	Nb	Nb
NbTi - NbTi	NbTi (niobium-titanium)	NbTi
NbTi - CuNi	NbTi	CuNi

BeCu: C17200, brass: C2600, CuNi: C7150, NbTi: Nb-47wt%Ti

Refrigerator for cable evaluation





Measurement -thermal conductance-

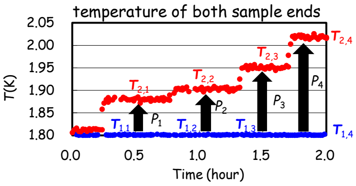
$$G = \frac{P_{n+1} - P_n}{T_{2,n+1} - T_{2,n}} \cdot L$$

G: thermal conductance per length (1cm)
P_n: n^{th} input power by manganin heater
$T_{2,n}$: steady temperature of thermometer 2
L : sample length (=55mm)

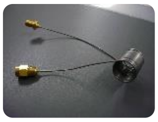
$$P_n = \int_{T_{1,n}}^{T_{2,n}} \frac{G}{L} dT, \quad P_{n+1} = \int_{T_{1,n+1}}^{T_{2,n+1}} \frac{G}{L} dT$$

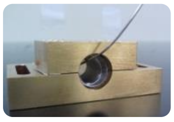
$$P_{n+1} - P_n = \int_{T_{1,n+1}}^{T_{2,n+1}} \frac{G}{L} dT + \int_{T_{2,n}}^{T_{1,n}} \frac{G}{L} dT \approx \int_{T_{2,n}}^{T_{2,n+1}} \frac{G}{L} dT$$

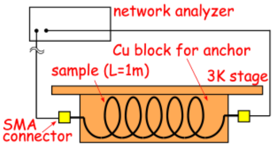
temperature of both sample ends



Measurement -attenuation-







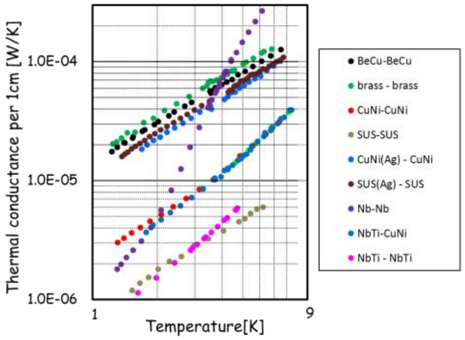
α: attenuation per length [dB/m]

$$\alpha[dB/m] = \frac{1.99\sqrt{\varepsilon_r}}{\log(D/d)} \sqrt{f} \left(\frac{\sqrt{\rho_d}}{d} + \frac{\sqrt{\rho_D}}{D} \right) + 9.09 \times 10^{-2} \sqrt{\varepsilon_r} \tan\delta \cdot f$$

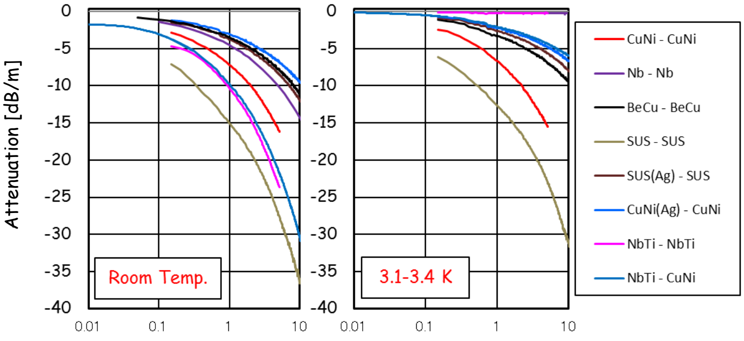
ε_r: relative permittivity of PTFE
ρ_D: resistivity of outer conductor
ρ_d : resistivity of center conductor
D: outer diameter of outer conductor
d: diameter of center conductor
tanδ: dielectric loss tangent
f: frequency (MHz)

Results

-thermal conductance-



-attenuation-



Summary

- We manufactured and evaluated various kinds of semi-rigid coaxial cables with ϕ 0.86mm.
- Most cables exhibited $G \sim T^{1.1 \sim 1.5}$ behavior in thermal conductance as expected. G for superconducting Nb coaxial showed steeper temperature dependence than others, and was small compared to literature, which were considered to be from deformation drawing process and impurity in Nb.
- Superconducting coaxial cables have extremely small attenuation property below Tc because of vanishment of electrical resistivity, which is advantageous compared to normal conducting ones in terms of low loss.

References

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