

RRR measurement of candidate materials

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Background

- For the KAGRA cryopayload, tungsten, molybdenum, beryllium copper, and phosphor bronze are candidate materials.
- We should determine which one is used after estimating how long the cooling time is.

Wiedemann-Franz law

- States that in metal, where free electrons play main roles on electric and heat transfers,

$$\frac{\kappa}{\sigma} = LT,$$

κ : thermal conductivity,

σ : electrical conductivity,

T : temperature,

$$L = 2.44 \times 10^{-8} \text{ Watt} \cdot \text{Ohm} \cdot \text{K}^{-2}$$

: Lorenz number

RRR measurement

- From the Wiedemann-Franz law,

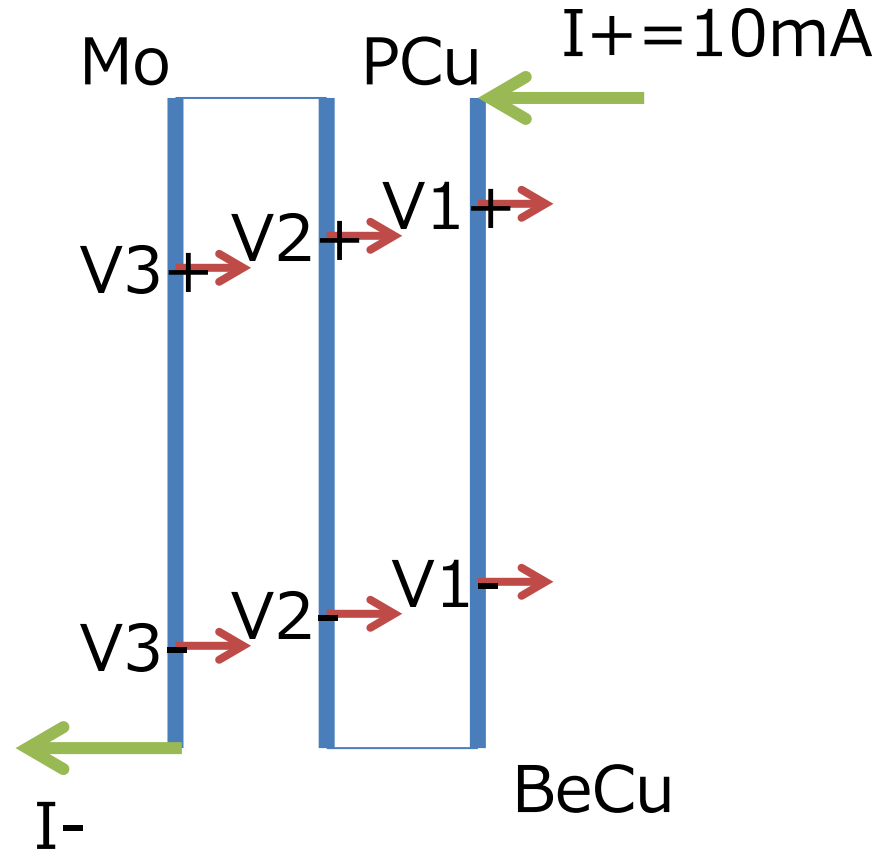
$$\text{RRR} := \frac{R(T_1)}{R(T_2)} = \frac{\sigma(T_2)}{\sigma(T_1)} = \frac{\frac{\kappa(T_2)}{LT_2}}{\frac{\kappa(T_1)}{LT_1}} = \frac{\kappa(T_2)}{\kappa(T_1)}$$

- By measuring RRR, we can roughly estimate thermal conductivity.

How to measure RRR

- We measure RRRs between room temp. ($T_1 \sim 300\text{K}$) and liquid helium temp. ($T_2 = 4.2\text{K}$).

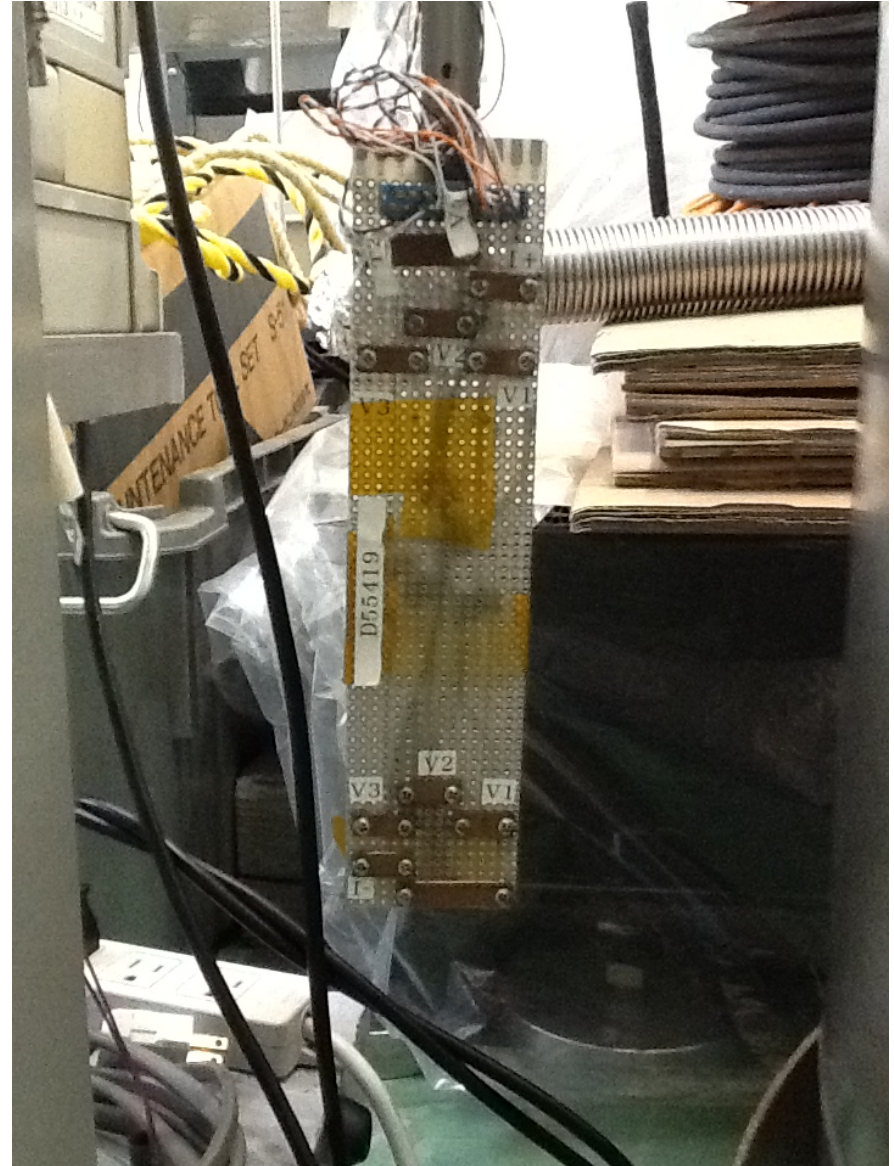
- $$R_i(T) = \frac{V_i^+ - V_i^-}{I}$$



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How to measure RRR

- Room temperature is measured by a thermocouple.
- Material 1=beryllium copper
- Material 2=phosphor bronze
- Material 3=molybdenum

Result@2012/2/28

	Resistance @290K	Resistance @ 4.2K	RRR
Beryllium copper	220 mOhm	169 mOhm	1.3
Phosphor bronze	260 mOhm	215 mOhm	1.2
Molybdenum	120 mOhm	4 mOhm	30

Discussion

- $RRR = \frac{R(300K)}{R(4K)} = \frac{\kappa(4K)}{\kappa(300K)}$ is small

is equivalent to κ does not become so large at 4K (which means cooling time becomes long).

- So our result predicts that molybdenum is not so good for the cryopayload compared with beryllium copper and phosphor bronze.

Discussion

- Beryllium copper and phosphor bronze are alloy.
→ We cannot apply Wiedemann-Franz law? (we cannot neglect the scattering effect by impurities)

Summery

- Molybdenum may no be good for the cryopayload compared with beryllium copper and phosphor bronze.
- For tungsten RRR is not measured yet (will be measured on this Friday?).
- For alloy RRR measurement does not work well? (we should check)

Fin