Evaluation of magnetic field dependence of the interface resistivity in REBCO tape with the contact-probing current transfer length method

Yosuke Atake*, Satoshi Ito, Kohki Takahashi, Hidetoshi Hashizume, Tohoku University, Japan, *Email : yosuke.atake.r6@dc.tohoku.ac.jp

1. Introduction

Since REBCO tape has multi-layered structure, there exists electric resistance at Cu/Ag and Ag/REBCO interfaces (**Interface resistance**)

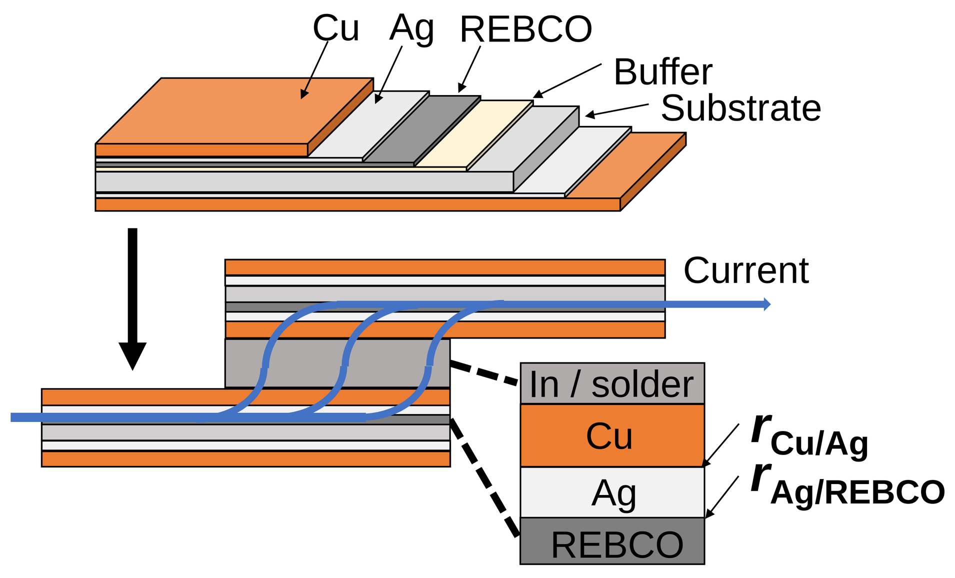


Fig. 1 Schematic of tape-to-tape joint

Interface resistivity [nΩcm²] ≡ resistance when joint area is 1 cm²
$= r_{Cu/Ag} + r_{Ag/REBCO}$

- Major factor of joint resistance
- Large variation depending on tape manufacturers and batches[1,2]
- Very few research evaluate even the temperature dependence

⇨ Detailed study for the interface resistivity is important

Purpose
Evaluation of the magnetic field and temperature dependence of interface resistivity

2. Method

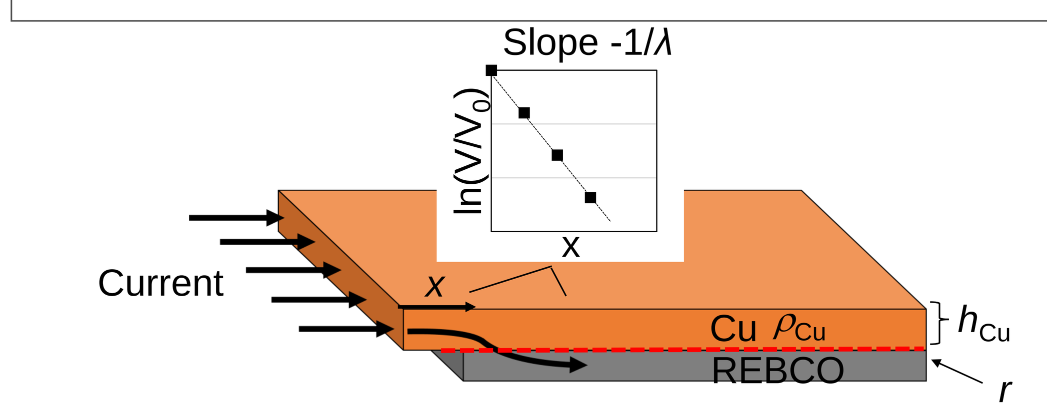
2.1. Method to measure the CTL

The current transfer length (CTL) is obtained from the electric potential on the metal surface where current transfers to REBCO layer

Current Transfer Length (CTL) method[3]

- Electric potential is described as Eq. (1)
- **CTL appears in Eq. (1) as λ (up to 1 mm)**
- **Interface resistivity r is derived from Eq. (2)**

$$V(x) = V_1 \exp\left(-\frac{x}{\lambda}\right) \quad (1) \qquad r = \lambda^2 \frac{\rho_{Cu}}{h_{Cu}} \quad (2)$$



ρ_{Cu} : Resistivity of Cu [Ωm] h_{Cu} : Hight of Cu layer [m]

Fig. 2 Schematic of CTL method

Contact-probing CTL method[2,4]

- **Contact probes are used as current leads and potential probes**
- Non-destructive measurement
- 3D current transfer

→ **Deriving the relationship between λ and r (calibration curve) with numerical analysis**

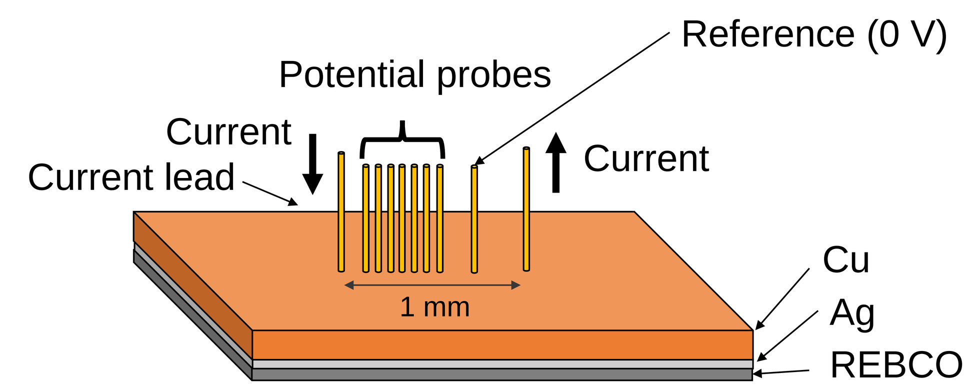


Fig. 3 Schematic of contact-probing CTL method

2.2. Experiment for CTL measurement

- CTL was measured at 10–70 K and 0–15 T.
- REBCO tape made by Sumitomo Electric Industry was used. (Thickness : Cu 20 μm, Ag 8 μm, GdBCO 2 μm)

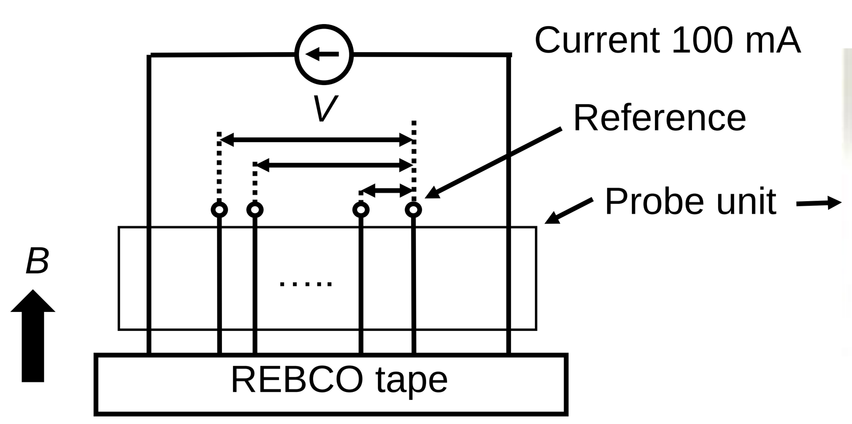


Fig. 4 Schematic of test section

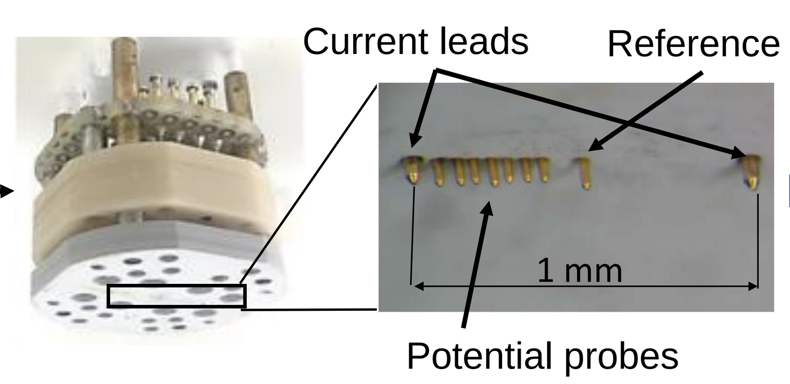


Fig. 5 Probe unit

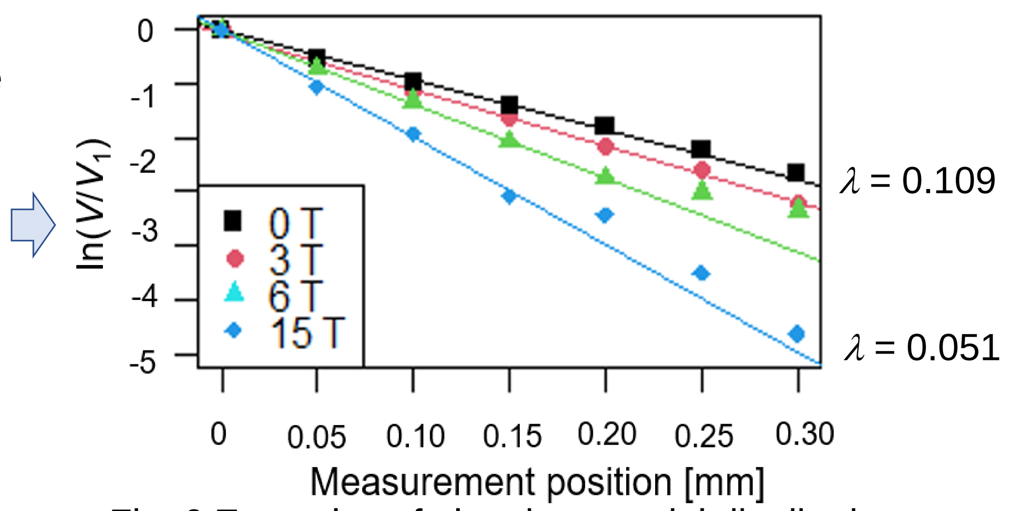
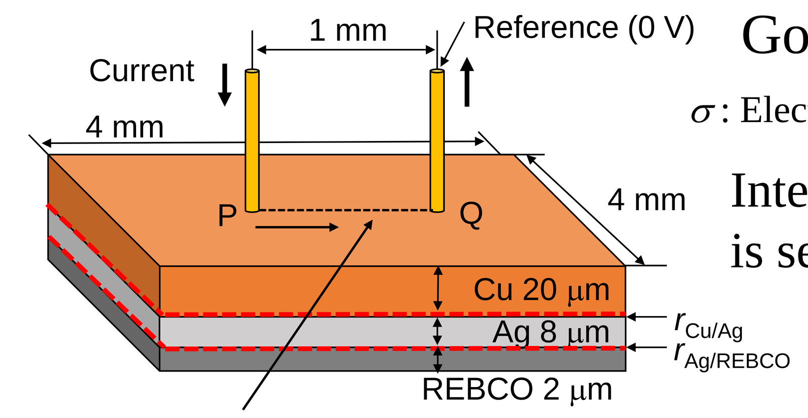


Fig. 6 Examples of electric potential distributions

2.3. Numerical analysis to obtain the relationship between λ and r

The CTL depending on the interface resistivity is derived from electric potential distribution.



Governing Eq. $\nabla \cdot (\sigma \nabla V) = 0$

σ : Electric conductivity [S/m] V : Electric potential [V]

Interface resistivity $r_{Cu/Ag} + r_{Ag/REBCO}$ is set as a parameter

Electric potential on PQ line was used to obtain the CTL

Fig. 7 Analytical model

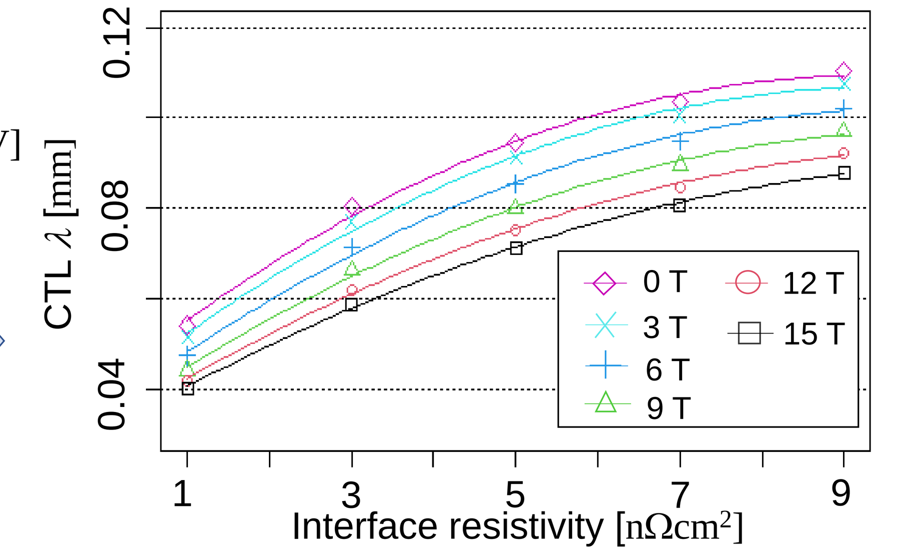


Fig. 8 Examples of the "calibration curves" (10 K, 0–15 T)

3. Result & Discussion

3.1. Magnetic field dependence

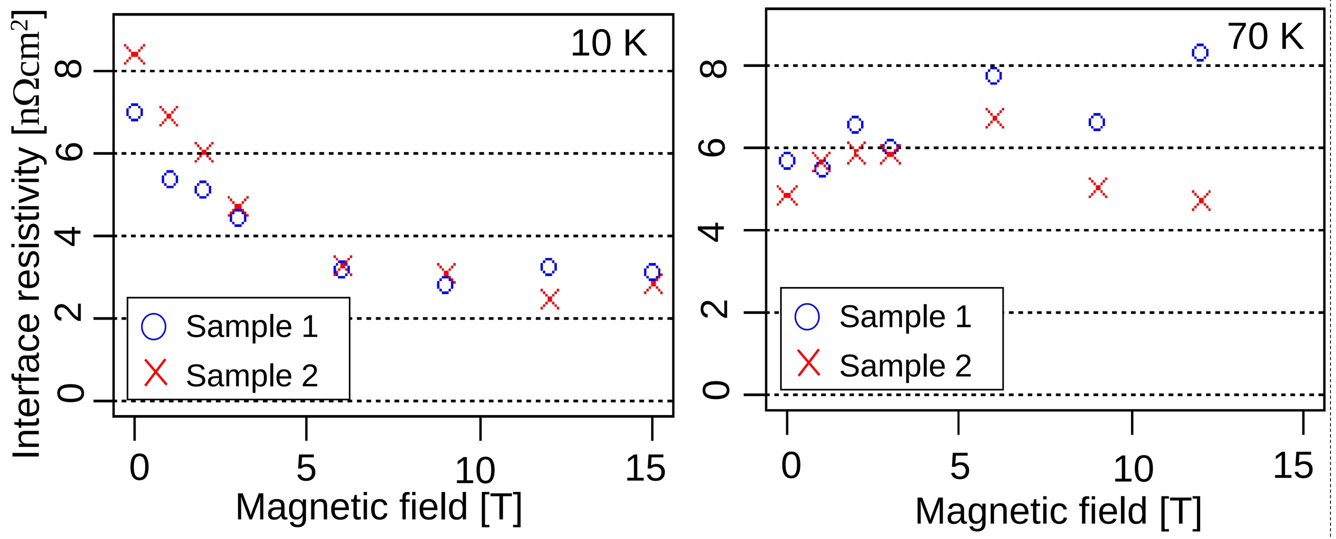


Fig. 9 Magnetic field dependence of interface resistivity

Interface resistivity decreases with increasing magnetic field at 10 K, but increases at 70 K.

Cu/Ag interface resistivity
Increases with increasing magnetic field
⇨ Influence of Ag/REBCO is larger at 10 K?

Hypothesis
10 K : REBCO dominates the behavior
70 K : Influence of Cu/Ag surpasses that of REBCO

Resistivity of YBCO along the *c*-axis (above T_c)[5]
Decreases with increasing magnetic field, but the higher temperature, the weaker the tendency becomes
⇨ Further research is needed

3.2. Temperature dependence

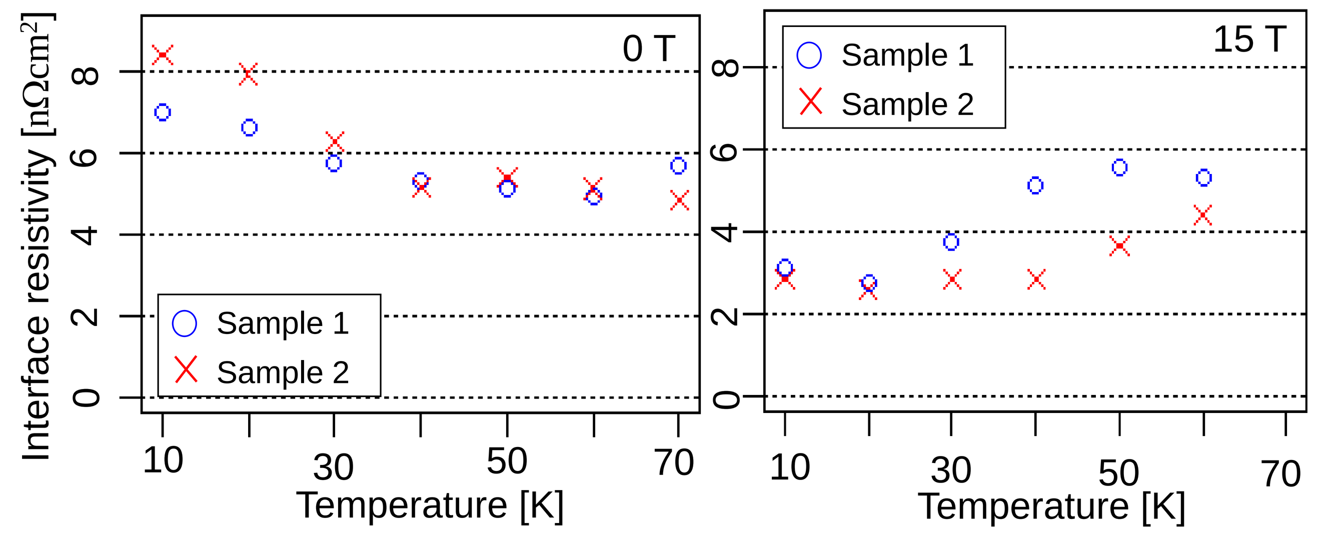


Fig. 10 Temperature dependence of interface resistivity

Interface resistivity decreases with increasing temperature at 0 T, but increase at 15 T.

Cu/Ag interface resistivity
Increases with increasing temperature
⇨ Influence of Ag/REBCO is larger at 0 T?

Hypothesis
0 T : REBCO dominates the behavior
15 T : Influence of Cu/Ag surpasses that of REBCO

Resistivity of YBCO along the *c*-axis (above T_c)[5]
Decreases with increasing temperature
⇨ Further research is needed

4. Conclusion & Future research

- ✓ Magnetic field and temperature dependence of interface resistivity was successfully evaluated with contact-probing CTL method.
- ✓ Interface resistivity decreases with increasing magnetic field at 10 K, but increases at 70 K
- ✓ Interface resistivity decreases with increasing temperature at 0 T, but increases at 15 T
- ☐ Need to measure Cu/Ag and Ag/REBCO interface resistivity separately to understand their behaviors in our future research

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