Heat transfer at a sapphire – indium interface in the 30 mK – 300 mK temperature range

J. Liberadzka\textsuperscript{1,3}, T. Koettig\textsuperscript{1}, J. Bremer\textsuperscript{1}, C. C. W. van der Post\textsuperscript{2} and H. J. M. ter Brake\textsuperscript{3}

\textsuperscript{1}CERN, Switzerland,  
\textsuperscript{2}Fontys School of Natural Sciences, Netherlands  
\textsuperscript{3}University of Twente, Netherlands
Content

- Motivation – AEGIS
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AEgIS:
Antimatter Experiment: Gravity, Interferometry, Spectroscopy

Goal:
direct measurement of the Earth’s gravitational acceleration \( g \) on antihydrogen within 1% accuracy

Antihydrogen formation:

\[
P_{s}^{*} + \bar{p} \rightarrow \bar{H}^{*} + e^{-}
\]
AEgIS apparatus lay-out

5T-magnet
Nominal current  170 A
Stored energy    419 kJ
Cold bore       250 mm

1T-magnet
Nominal current  85 A
Stored energy    29 kJ
Cold bore       160 mm

Antihydrogen in a Penning trap below 100 mK
Ultra-Cold Electrodes

- 10 electrodes cooled to 100 mK
- Made of radiation hard materials
- Ultra-high vacuum (< $10^{-12}$ mbar)
- Electrical insulation for up to 1kV between neighbouring electrodes
- geometry with very high precision

Sapphire as electrical insulator and good thermal conductor at low temperature

Thermal performance of a metal – dielectric Interface to be studied in 30 – 300 mK range
CERN Cryolab DR

T = 1.3 K

1 K pot

T = 0.6 K

Still

Mixing Chamber

20 mK < T < 300 mK

Pictures by Patrick Wikus
Experimental setup

Sapphire disk

\[ \phi = 20 \, mm \]

1 mm
Experimental setup

Polished surfaces
Experimental setup

Indium vapor deposited + 125 μm foil
Experimental setup
Experimental setup
Experimental setup

T_{st} \quad EH

Stamp

T_{pl}

Platform
Experimental setup
Experimental setup

Platform

Stamp EH

$T_{st}$

$T_{pl}$
Experimental setup
Experimental setup

125 μm indium foil
Experimental setup

Superconducting solenoid

Stamp (EH)

Platform

3He/4He mixture

Superconducting solenoid
Temperature as a function of applied heat load, Indium in normal conducting state

![Graph showing temperature as a function of power for different TMC values.](image)

- TMC 62 mK
- TMC 50 mK
- TMC 30 mK

Power [μW] vs. Temperature [mK] for TMC 30, Stamp, TMC 30, Platform, TMC 50, Stamp, TMC 50, Platform, TMC 70, Stamp, TMC 70, Platform.
Temperature as a function of applied heat load, Indium in superconducting state
Kapitza resistance

\[ R_{\text{tot}} = \frac{A}{4Q} \left( T_{\text{st}}^4 - T_{\text{pl}}^4 \right) \]

\[ \alpha = 4^\circ \]
\[ t = \frac{4Z_1Z_2}{(Z_1 + Z_2)^2} \]

helium – copper only \(10^{-5}\)
Thermal resistivity of the compressed setup

\[ R_{tot} = \frac{A}{4Q} \left( T_{st}^4 - T_{pl}^4 \right) \]

- Indium SC
- Indium NC

- TMC 20, Indium SC
- TMC 50, Indium SC
- TMC 70, Indium SC
- TMC 100, Indium SC
- TMC 30, Indium NC
- TMC 50, Indium NC
- TMC 70, Indium NC
Thermal resistivity without compressing force

Thermal resistivity [cm$^2$ K$^4$ W$^{-1}$] vs Temp stamp [mK]

- TMC 30, Indium NC
- TMC 50, Indium NC
- TMC 70, Indium NC
- TMC 100, Indium NC
- TMC 30, Indium SC
- TMC 50, Indium SC
- TMC 70, Indium SC
- TMC 100, Indium SC

Indium NC
Indium SC

ECD 2016

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Thermal resistivity with NC indium

![Graph showing thermal resistivity vs. temp stamp for different samples](image)

- **TMC 30 - no force, In NC**
- **TMC 50 - no force, In NC**
- **TMC 70 - no force, In NC**
- **TMC 100 - no force, In NC**
- **TMC 30 - with force, In NC**
- **TMC 50 - with force, In NC**
- **TMC 70 - with force, In NC**
Thermal resistivity of the setup with 1 mm and 1.5 mm sapphire disk with NC indium

*Courtesy T. Eisel, PhD Thesis, CERN, Cryolab
Conclusions

• Surface preparation essential – polished surface with vapor deposited indium gives the best results

• The presence of the magnetic field shifts the dielectric – metallic interface and significantly changes the overall resistivity

• Compressing force doesn’t influence the results with indium in normal conducting state

• The electrode mounting structure in AEgIS can be removed after a good connection is obtained