Technische Universität Braunschweig

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Measuring emissivity of contact material using a thermography camera

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Agenda

- Motivation and Basics
- Experimental setup for emissivity determination of liquid metals
- Emissivity of copper
- Challenges
- Conclusion

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Motivation and Basics

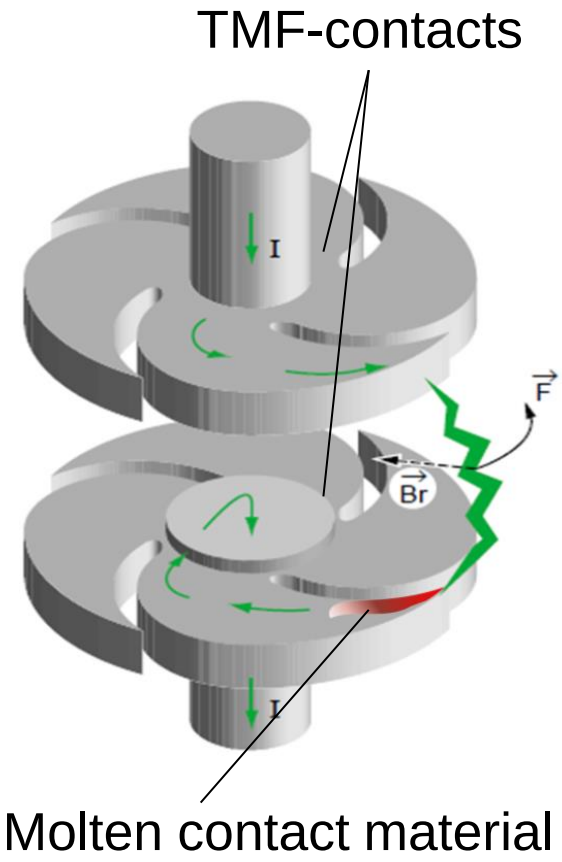
Arc behavior between TMF switching contacts in vacuum

- TMF (Transversal Magnetic Field) contacts induce circular arc movement
- Arc root temperature is above melting point of contact material
- A trace of molten surface material is generated by the arc

Benefit of knowing the arc root temperature

More precise simulation models can be developed

Improved understanding of re-ignition behavior



Motivation and Basics

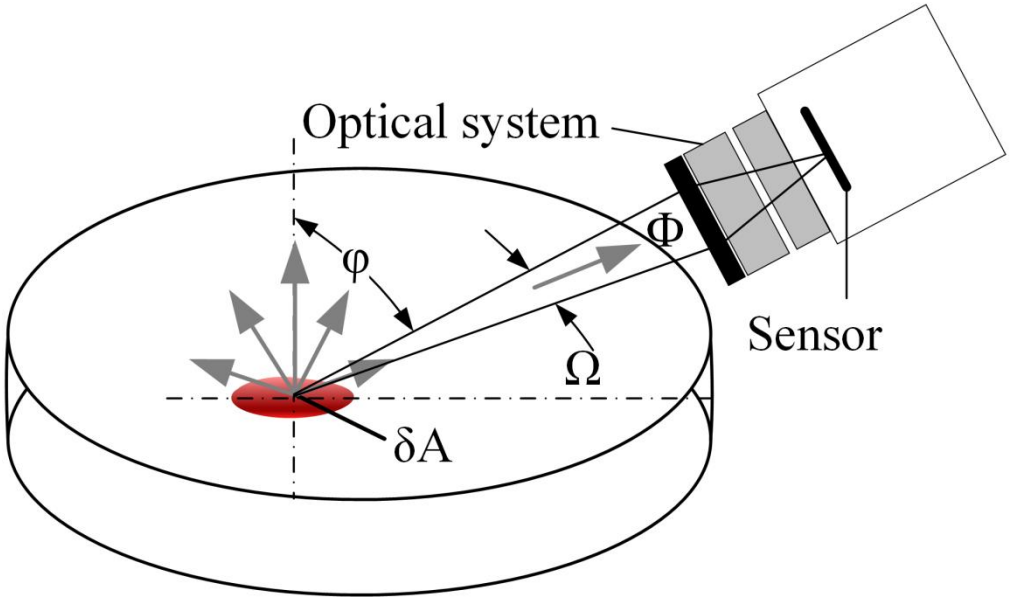
Determination of arc root temperature using a thermography camera

- Molten contact material radiates over entire spectral range
- Radiance is proportional to temperature
- Value of radiance depends on emissivity ε
- ε depends on temperature, wavelength and emission angle

$$L = \phi / (\varepsilon(T, \lambda, \varphi) \cdot \tau \cdot \cos(\varphi) \cdot \Omega \cdot \delta A)$$

$$T = f(L)$$

φ: Emission angle
Ω: Irradiated solid angle
δA: Analyzed area element
ϕ: Radiant flux of δA



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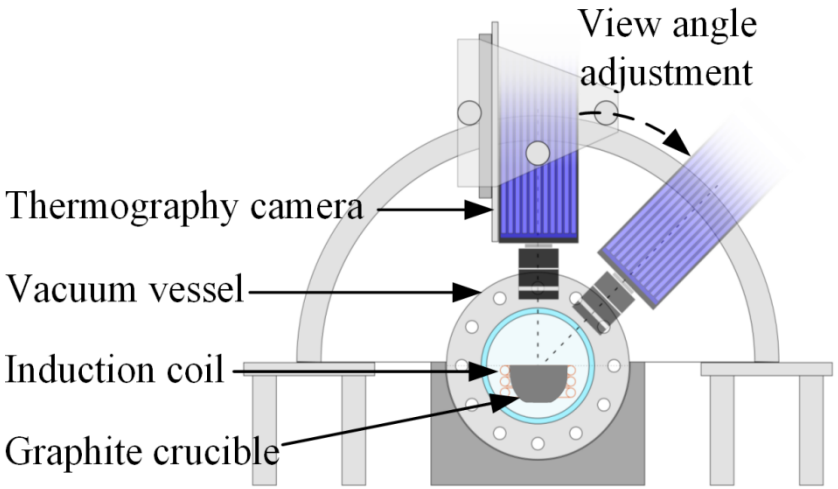
Experimental setup for emissivity determination of liquid metals

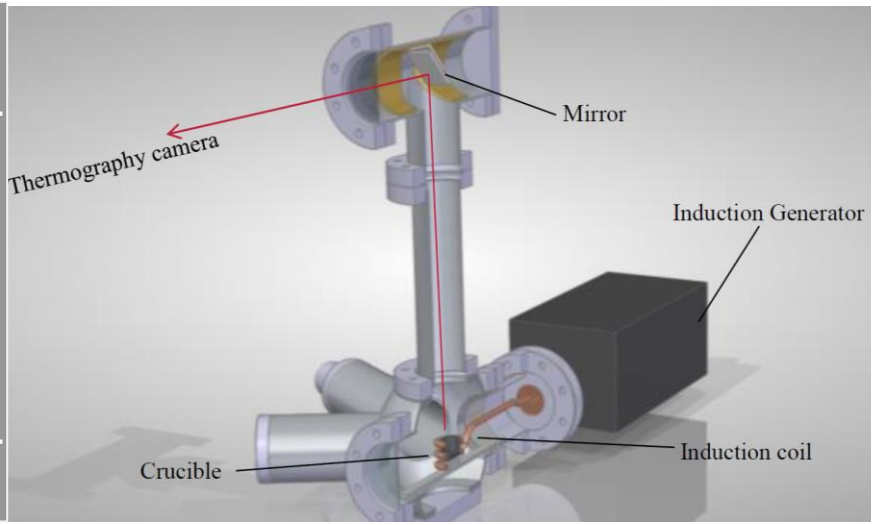
Experimental setup overview

- Development of an experimental setup to determine the emissivity of liquid metals
- An induction coil is used to melt the metal sample in a graphite crucible
- Melting in vacuum or inner gas condition with argon
- An adjustable camera position is used to change the recorded emission angle

Schematic overview



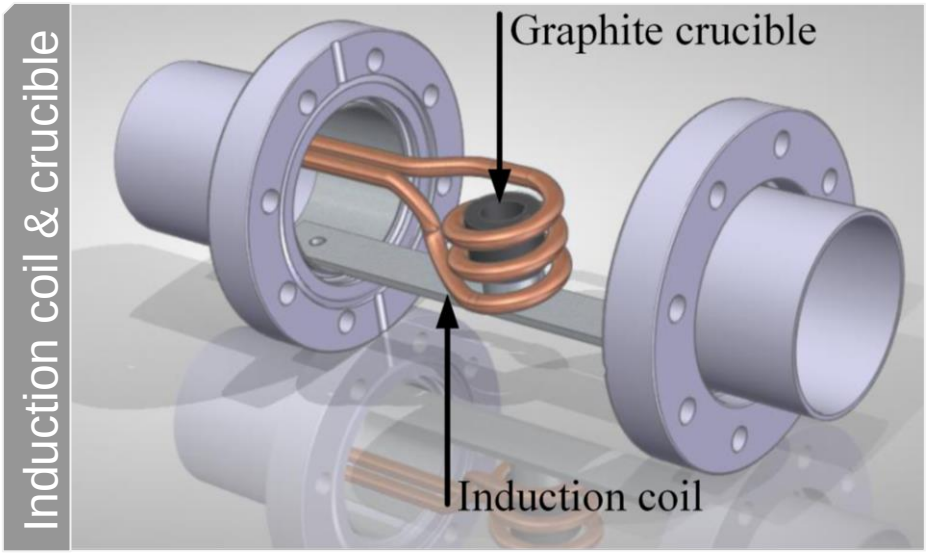
Experimental setup

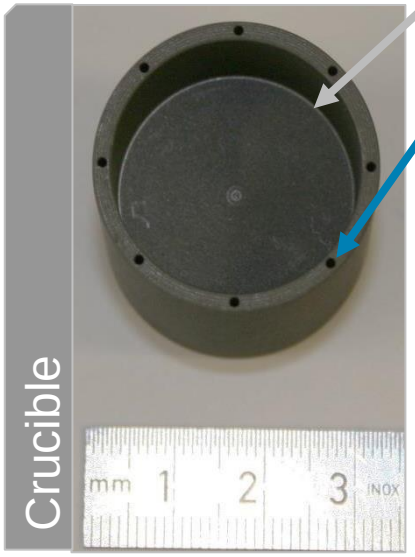


Experimental setup for emissivity determination of liquid metals

Graphite crucible

- Black body bores in crucible as reference for the temperature measurement
- Black bodies have an emissivity of ε ≈ 1 → direct temperature measurement is possible
- Melt temperature can be determined using black body radiation





Bore for the sample (L_{Sample})

Bores for the black body (L_{bb})

$$\varepsilon = L_{sample}/L_{bb}$$

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Experimental setup for emissivity determination of liquid metals

Emissivity of copper

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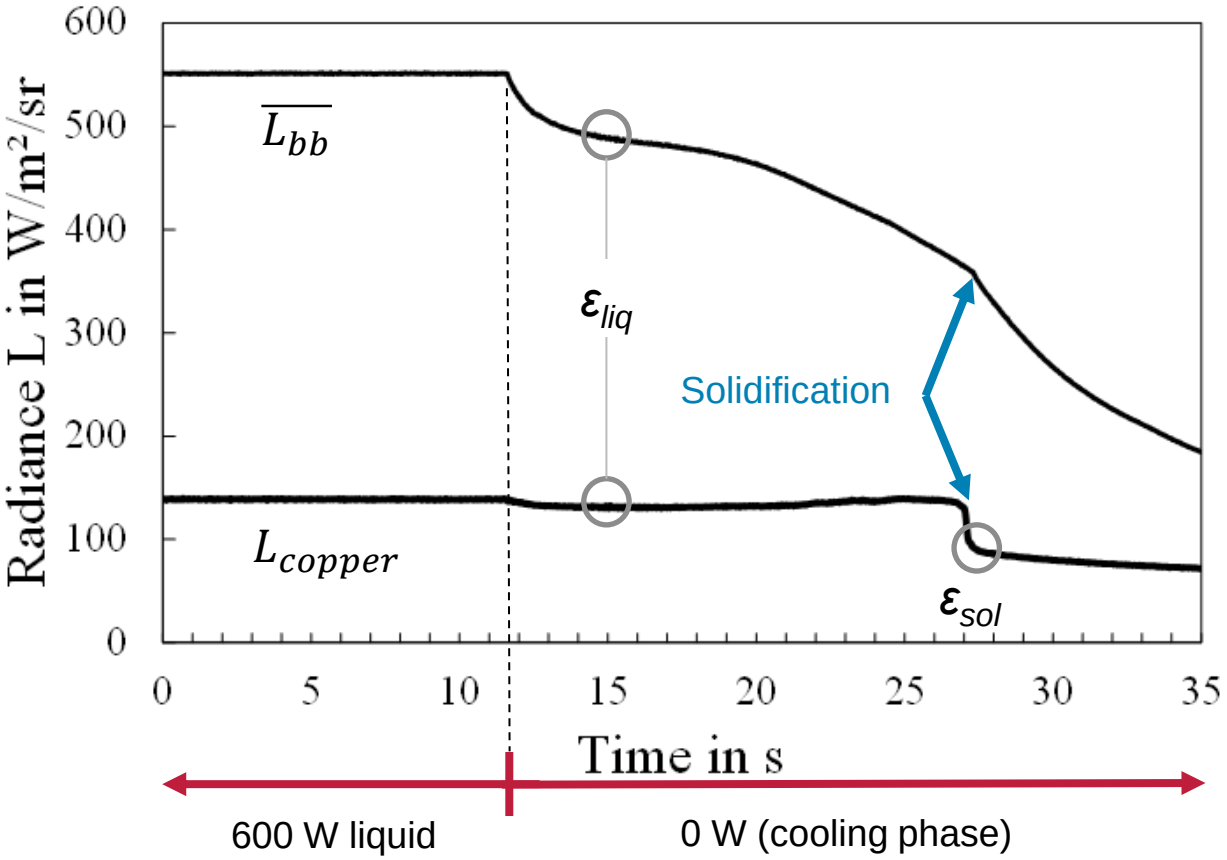
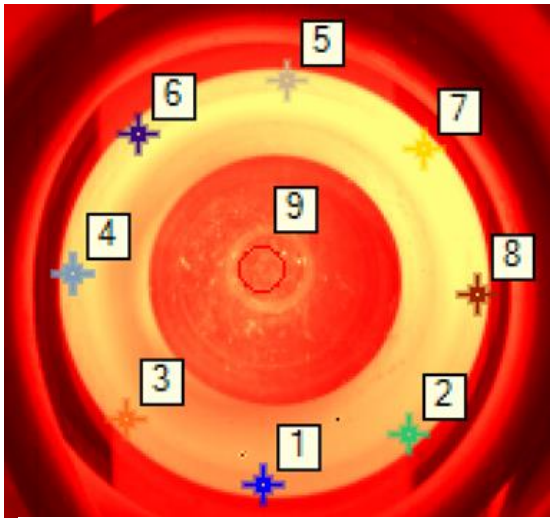
Emissivity of copper

Determination of emissivity of liquid and solidified copper



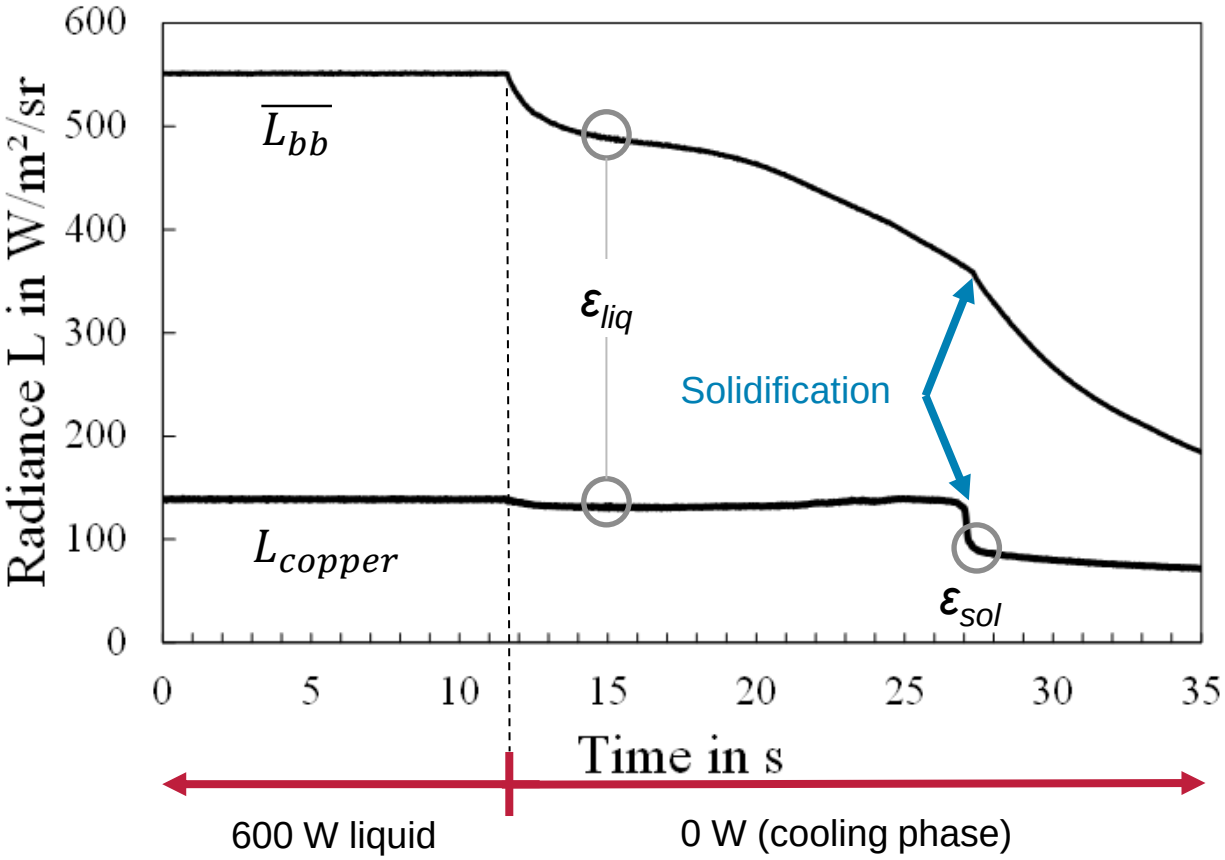
Recorded during heating phase



- 1 - 8: black bodies (L_{bb})
- 9: copper (L_{copper})

Emissivity of copper

Determination of emissivity of liquid and solidified copper



Emissivity of copper:
$\varepsilon_{liq} = 0.053$
$\varepsilon_{sol} = 0.035$

Valid for:
Temperature T = 1358 K
Wavelength λ = 1.5 – 1.7 µm
Emission angle φ = 0°

The estimated confidence interval is 0.01

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Challenges

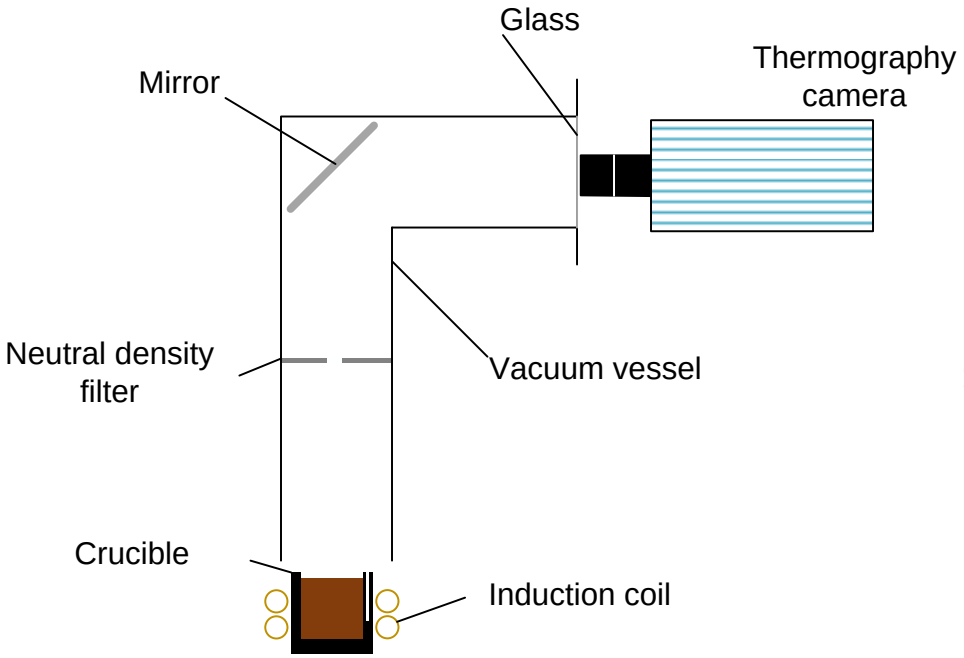
Previous Challenges with copper

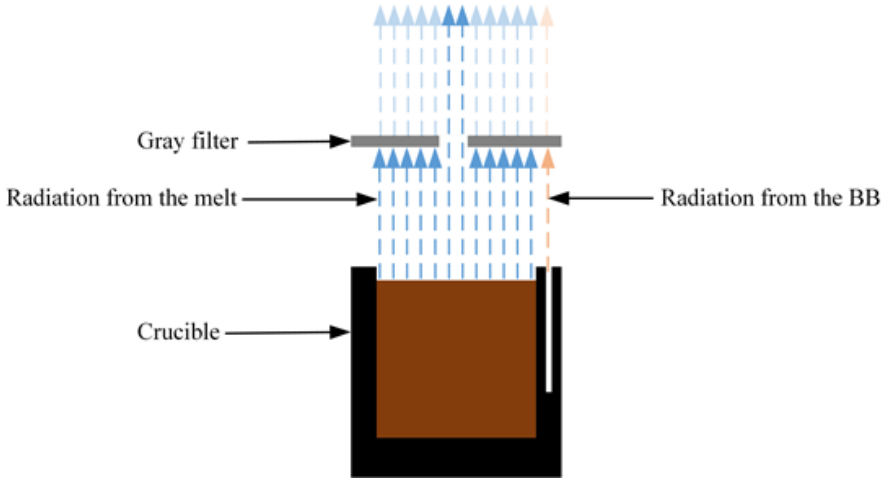
Pollution of melt after frequent use

→ using crucible for only a few experiments (about 5 times)

Limited measurement range of thermography camera

→ damping of blackbody radiation with neutral density filter



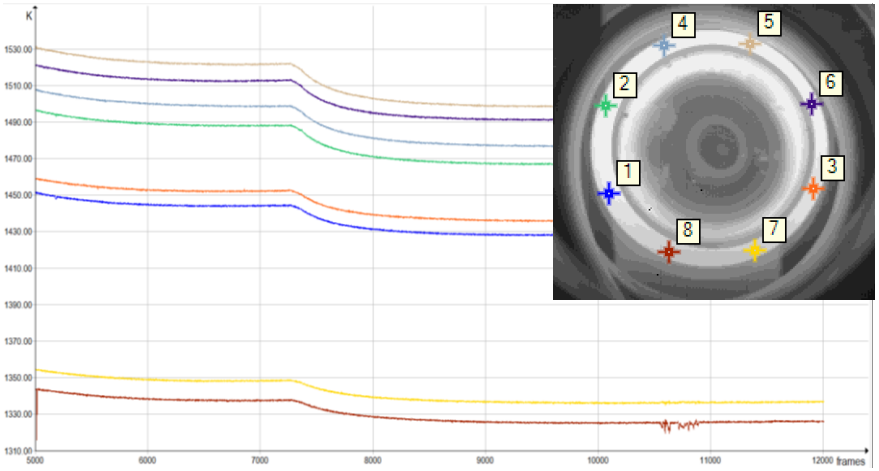


Challenges

Previous Challenges with copper

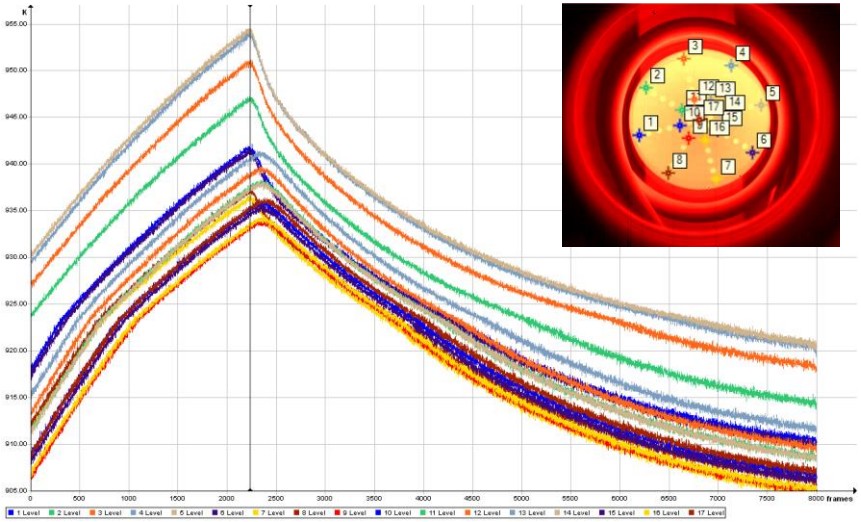
Temperature differences in crucible edge

→ several blackbody radiators in the edge for averaging blackbody temperature



Temperature gradient between crucible edge and melt

→ emissivity investigations during cooling phase (determination of the thermal equilibrium)

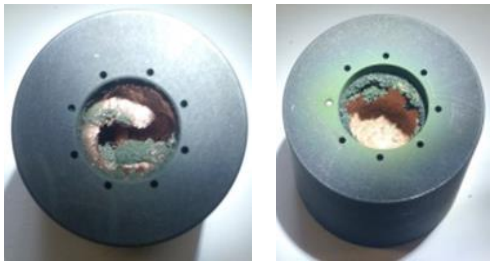


Challenges

Challenges with copper chromium

Melting of copper chromium is more complex than melting copper

Chromium is oxygen affine →



→ increasing vacuum quality

→ heating crucible in advance to outgas enclose gases

Chromium is paramagnetic

Chromium wets the graphite surface →

→ increasing crucible height and wall thickness

→ using zirconia

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Conclusion

Surface temperature of molten contact material can be determined using a thermography camera

Emissivity of investigated material must be known

A special experimental setup to quantify emissivity of molten material was constructed

Setup and methodology are confirmed by determination of copper emissivity

Next step is investigation of copper chromium emissivity

Thank you for your attention

Acknowledgement

ABB AG
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