$AddH_2$ – SP2: Material Characterisation by Determining Thermophysical Properties and Process Data

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Aims / Objectives

- **Motivation:** Carbon-free process heat
  → H_2-based combustion becomes increasingly important
- **Material Innovation:**
  → Al_2O_3-ceramics are promising for high-temperature applications [1]
  → Enhancement of the resistance to thermal shock
  → Additive manufacturing enables the combination of closed micropores with functional macrocavities
- **Experimental Focus**:
  → Investigation of the impact of H_2 & CH_4 combustion atmosphere on additively manufactured Al_2O_3-ceramics
  → Methane combustion as reference case
  → Determination of the thermophysical properties of undamaged and long-term aged samples
- **Objective:** Supporting the transition to sustainable, decarbonised industrial processes

Materials / Methods

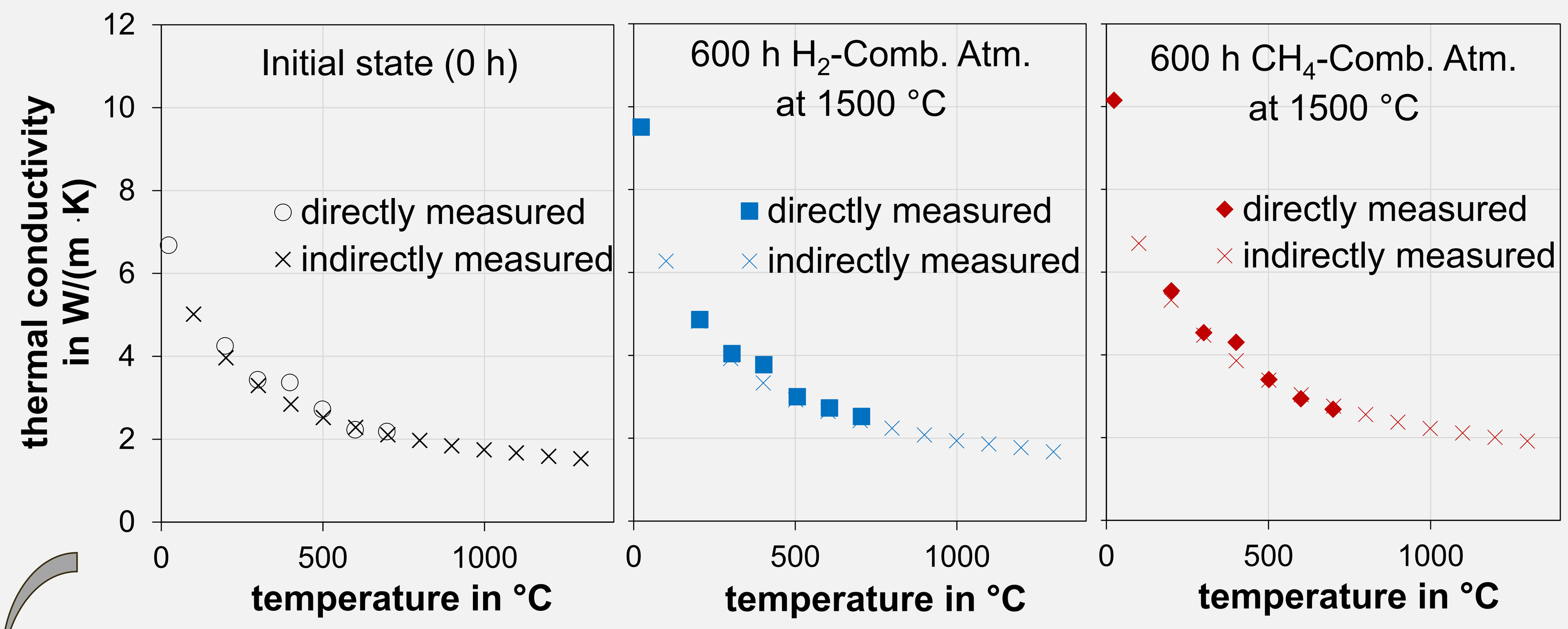
- Samples: Additively manufactured from Al_2O_3-ceramics
- Thermophysical properties:

Property	Measuring device
Thermal diffusivity a	Laser Flash Apparatus (LFA)
Effective thermal conductivity λ_{eff}	Transient-Plane-Source-System (TPS / Hot Disk)
Specific heat capacity c_p	High-temperature calorimeter (HTC)
Thermal expansion dL/L & α	Dilatometry (DIL)

- Process data:
  → Kinetics of damage, storage of gases
  → Thermogravimetric analyses of the ceramics with H_2 and H_2 -combustion atmosphere using a high-temperature magnetic suspension balance (HT-MSB)

Results

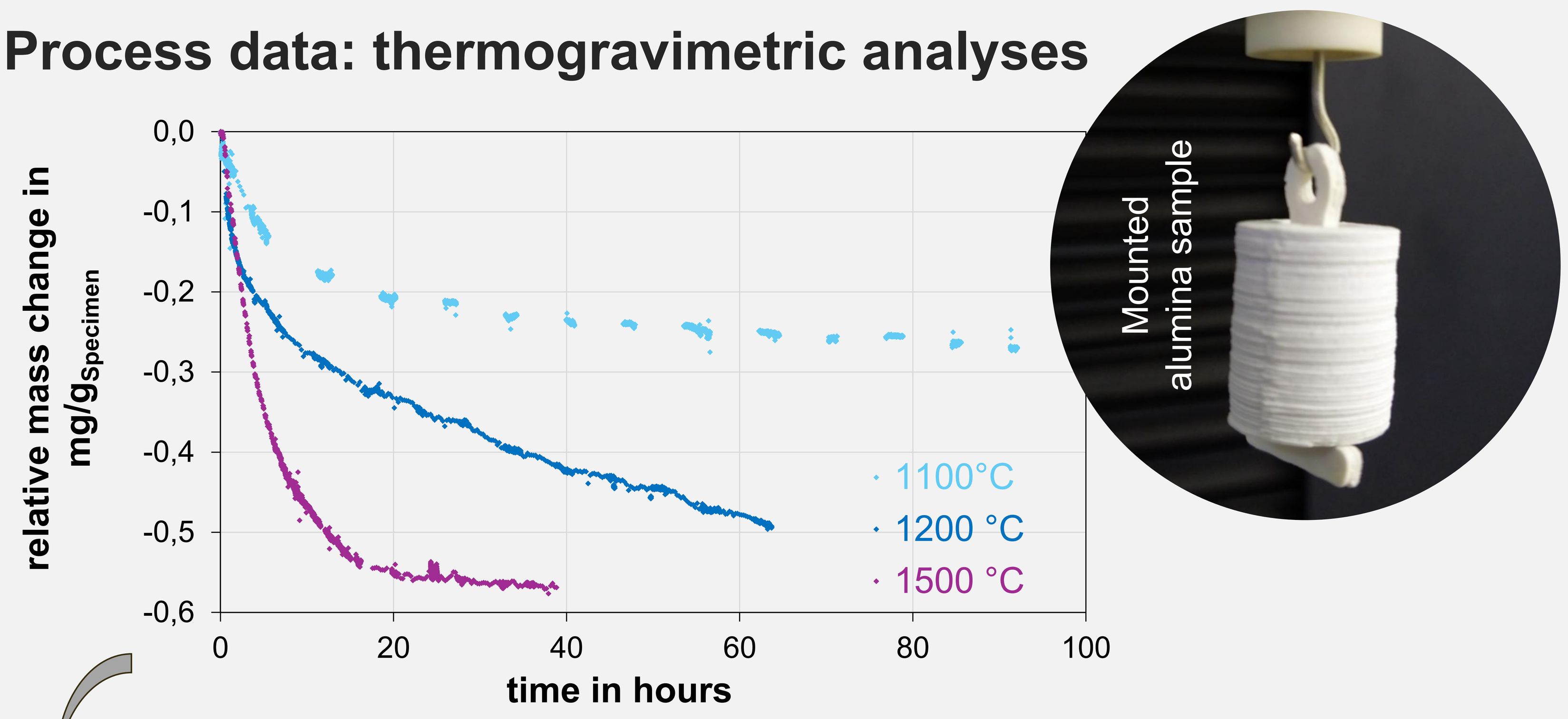
Thermophysical properties: thermal conductivity $\lambda = a \cdot \rho \cdot c_p$



Comparison of direct TPS measurements of thermal conductivity with indirect values calculated from thermal diffusivity (LFA) and specific heat (HTC)

- Comparison of direct and indirect measurements
  ➡ Methods show good agreement [2]
- Robustness of our findings: methods cross-validate each other

Process data: thermogravimetric analyses



Examination of alumina samples in 1.1 bar of pure H_2 at different temperatures (Dynamic Gas Dosing: 0.04 L(STP)/Min H_2)

- Temperature-dependent rate of mass loss
- Active vs. Passive degradation
- Possible stabilisation

Conclusions

- Specific heat and thermal expansion remained stable
  ➡ Bulk composition and phase content are unaffected
- Thermal conductivity and diffusivity increased
  – In both, H_2 and CH_4 combustion atmospheres
  – Influence of CH_4-Comb. Atm. higher than H_2-Comb. Atm.
  ➡ Changes in microstructure indicated
- No significant mass change in vacuum or helium atmosphere
- Mass loss in H_2 due to the reduction of Al_2O_3

References

[1] M. Ribeiro Gomes, T. Leber, T. Tillmann, D. Kenn, D. Gavagnin, T. Tonnesen, J. Gonzalez-Julian, Towards H_2 implementation in the iron- and steelmaking industry: State of the art, requirements, and challenges for refractory materials, J. Eur. Ceram. Soc. 44 (3) (2024) 1307–1334

[2] K. Markuske, F. Kerber, R. Wulf, C.G. Aneziris, T.M. Fieback, Investigation of the impact of hydrogen and hydrogen combustion atmosphere on additive manufactured alumina in the high-temperature range, Presentation at the XIX ECerS Conference (2025) Dresden, Germany

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