

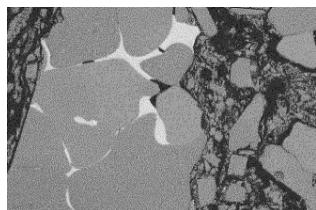
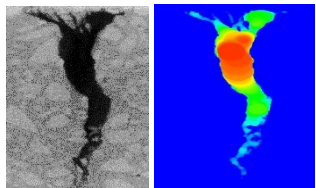


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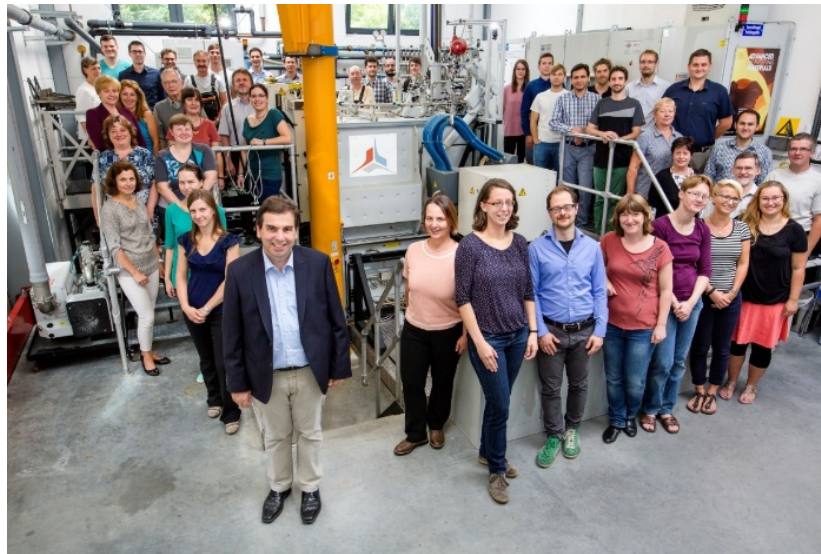


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Functional composite material structures for hybrid concepts in high temperature applications



C.G. Aneziris, P. Gehre, J. Hubalkova, S. Dudczig



Institute of Ceramics, Refractories and Composite Materials
Zentrum für effiziente Hochtemperatur Stoffwandlung

Professorship of Ceramics, Refractories and metal-ceramic Composites | Agricolastrasse 17 | 09599 Freiberg

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SFB 920



DFG Deutsche
Forschungsgemeinschaft

GRK 2802,
2022 – 2027
2027 - 2031

Aneziris, Volkova

FOR 3010,
2020 – 2022
2023 - 2026

Aneziris, Heilmaier

SFB 920,
2011 – 2023

Aneziris, Biermann

SFB 799,
2008 – 2020

Biermann, Aneziris

SPP 1418,
2009 – 2016

Aneziris



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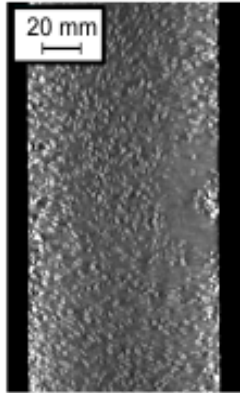
Recycling and inert anodes

**Refractory composites,
sandwich macrostructures**

**Filtration, Metal-Quality,
3D-Hybrid, Metal Recycling**

**Metal/Ceramic-Composites
Non-conventional shaping**

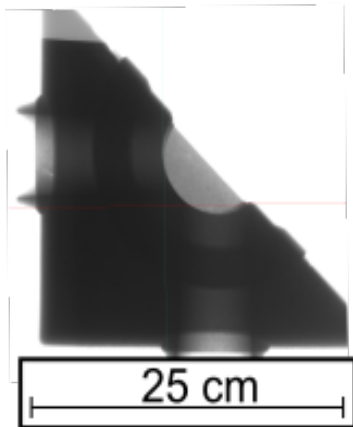
**Thermal shock resistance²
less carbon, nano additives**



H₂-Gas burner
casing
Grain size: 0-2 mm
0.5 % shrinkage
1.5 kg

Spider brick
Grain size: 0-3 mm
0.1 % shrinkage
2.2 kg

Stopper / Electrode
Grain size: 0-0.6 mm
0.5 % shrinkage
8 kg



Pressure Slip Casting

Heating shield for
aas turbines
Grain size: 0-3 mm
0.1 % shrinkage
3 kg



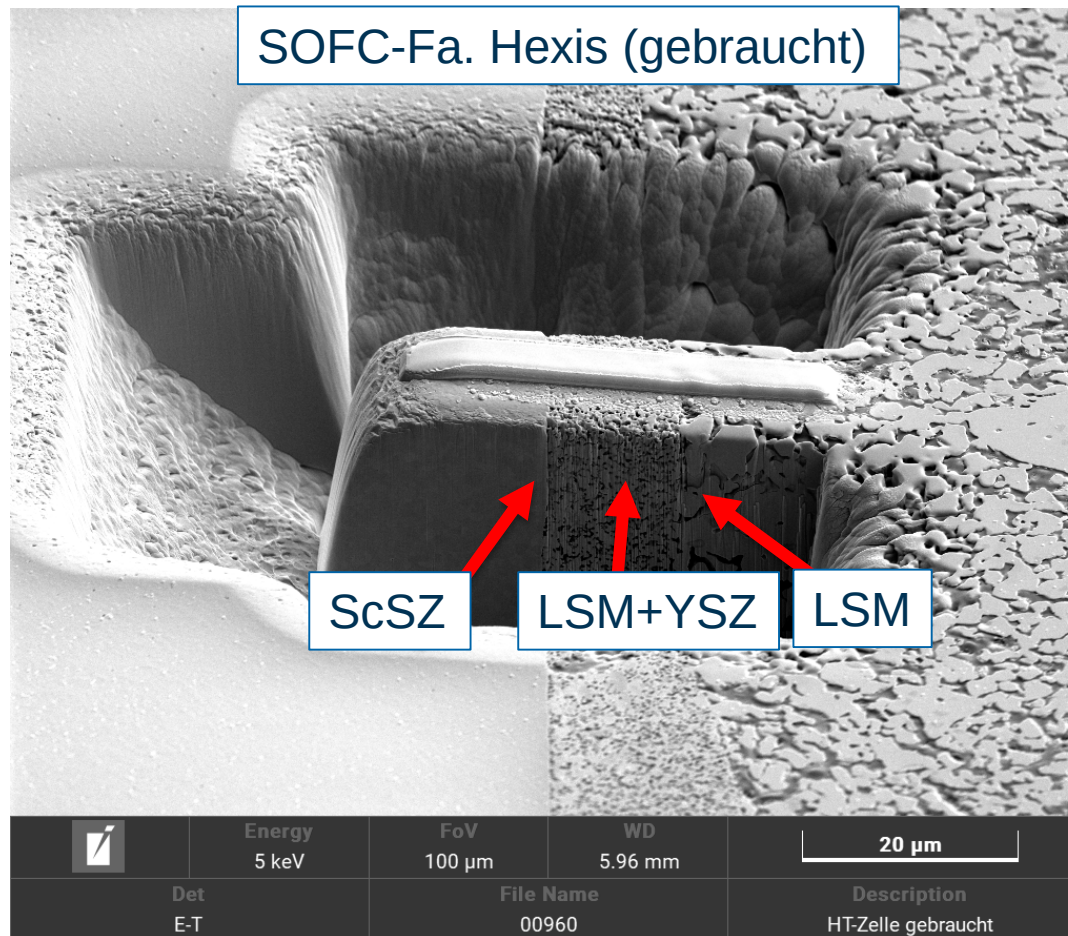
Functional ceramics and metal/ceramic composites
contribute to the energy transition and to a sustainable circular economy.

Examples:

- ➔ SOFC (energy converters)
Batteries (energy storage systems)
- ➔ Filter ceramics for recycling of metals and light weight structural components



Circular Economy: Recycling of SOFC



GEFÖRDERT VOM



Bundesministerium
für Bildung
und Forschung

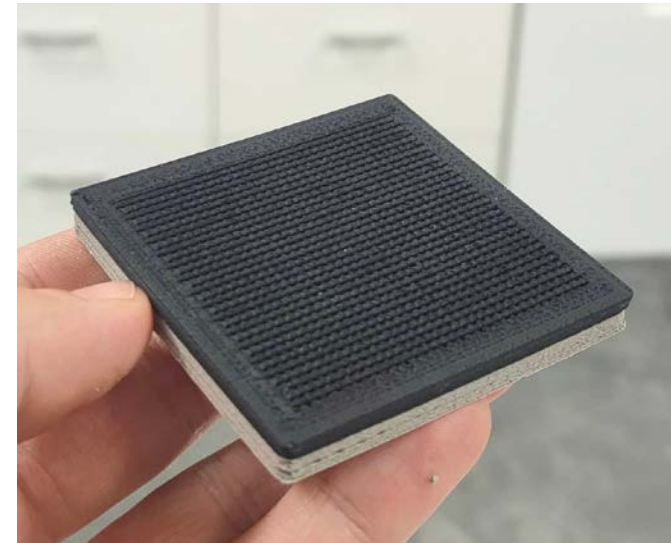
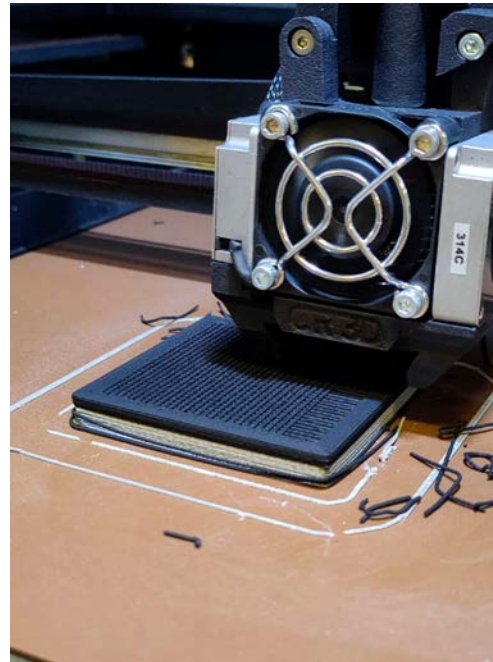


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Leitprojekt
H₂Giga



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Fused Filament Fabrication and 3D printing of SOFC

GEFÖRDERT VOM



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und Forschung



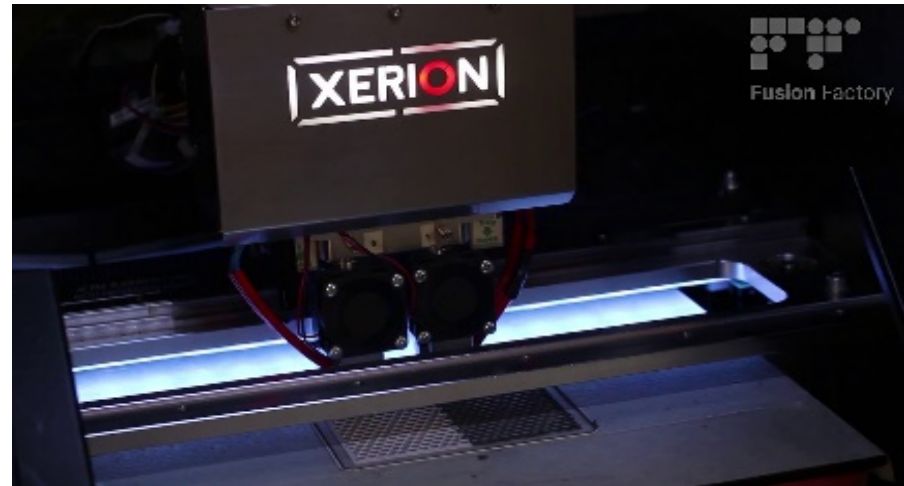
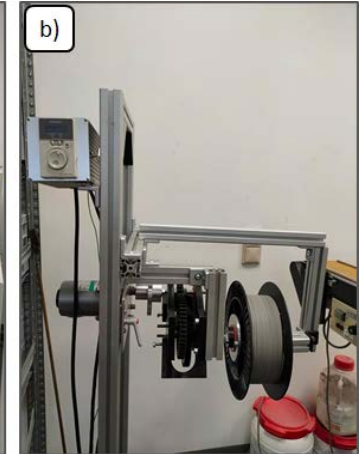
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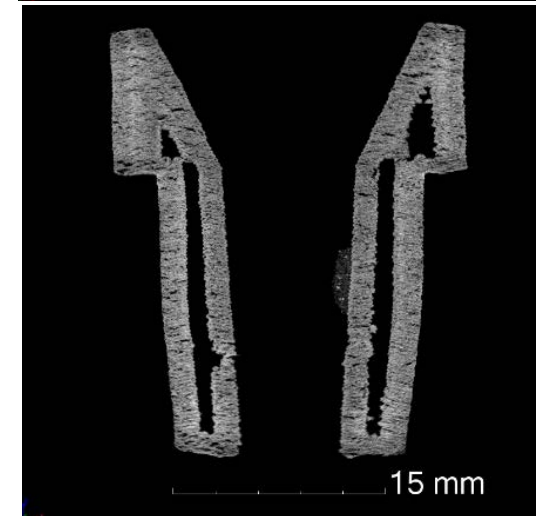
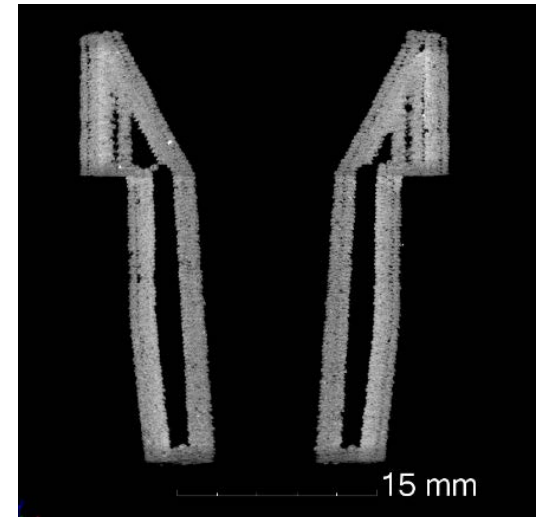
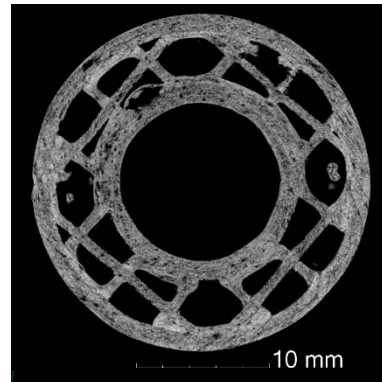
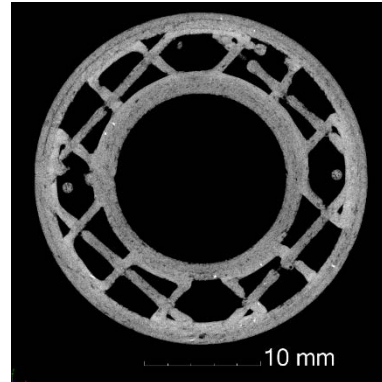
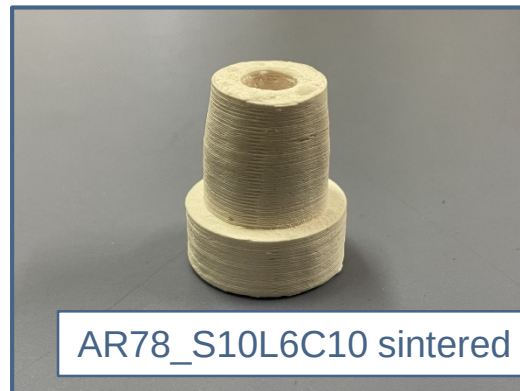


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3D FFF* für Smart Composite

*: Fused Filament Fabrication

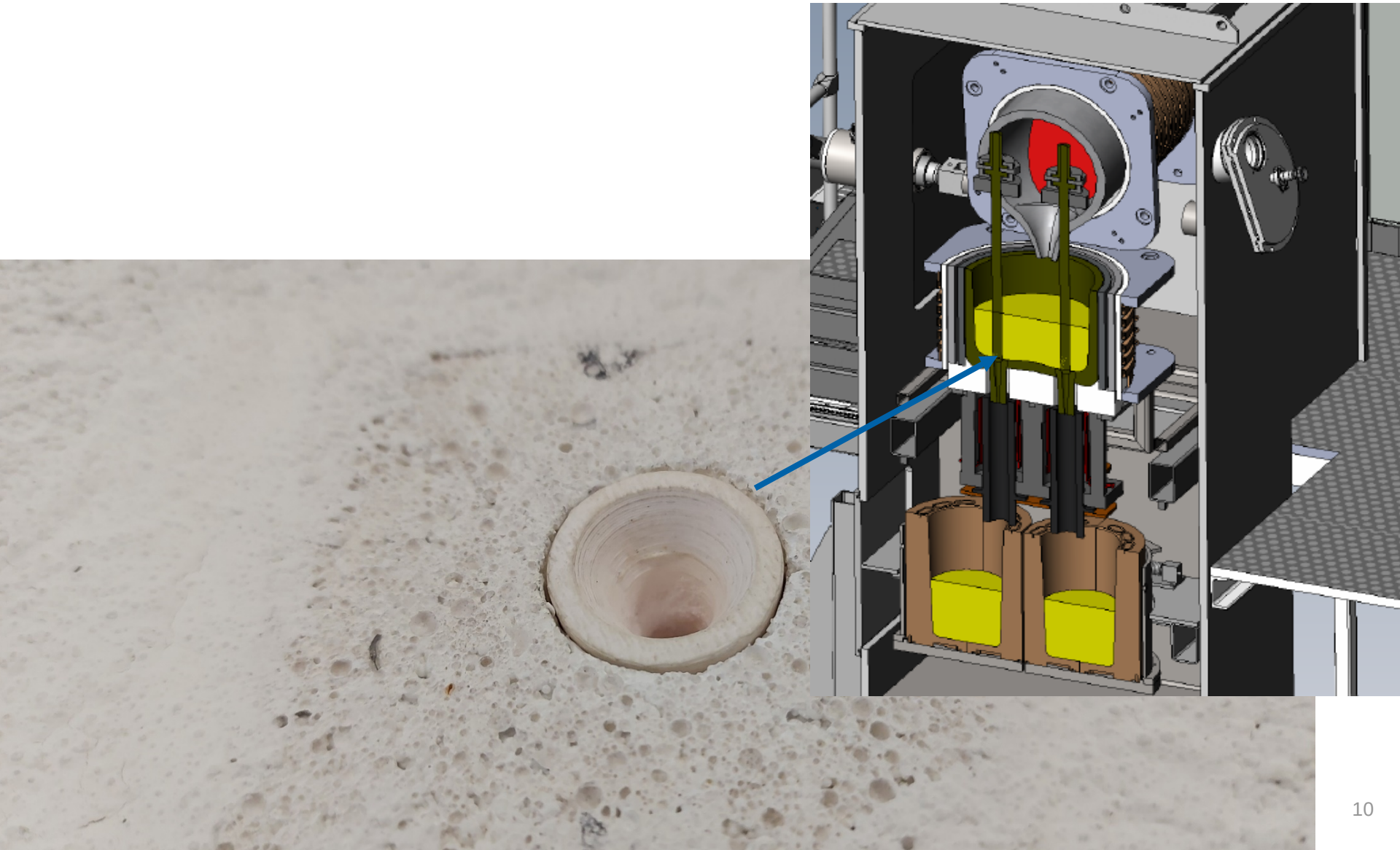




Ceramics **2023**, 6, 475–491.

<https://doi.org/10.3390/ceramics6010027>

Patent application Aneziris, Malczyk, Yaroshevskyi, Dudczig, Hubalkova
DE 10 2022 001 271.5.

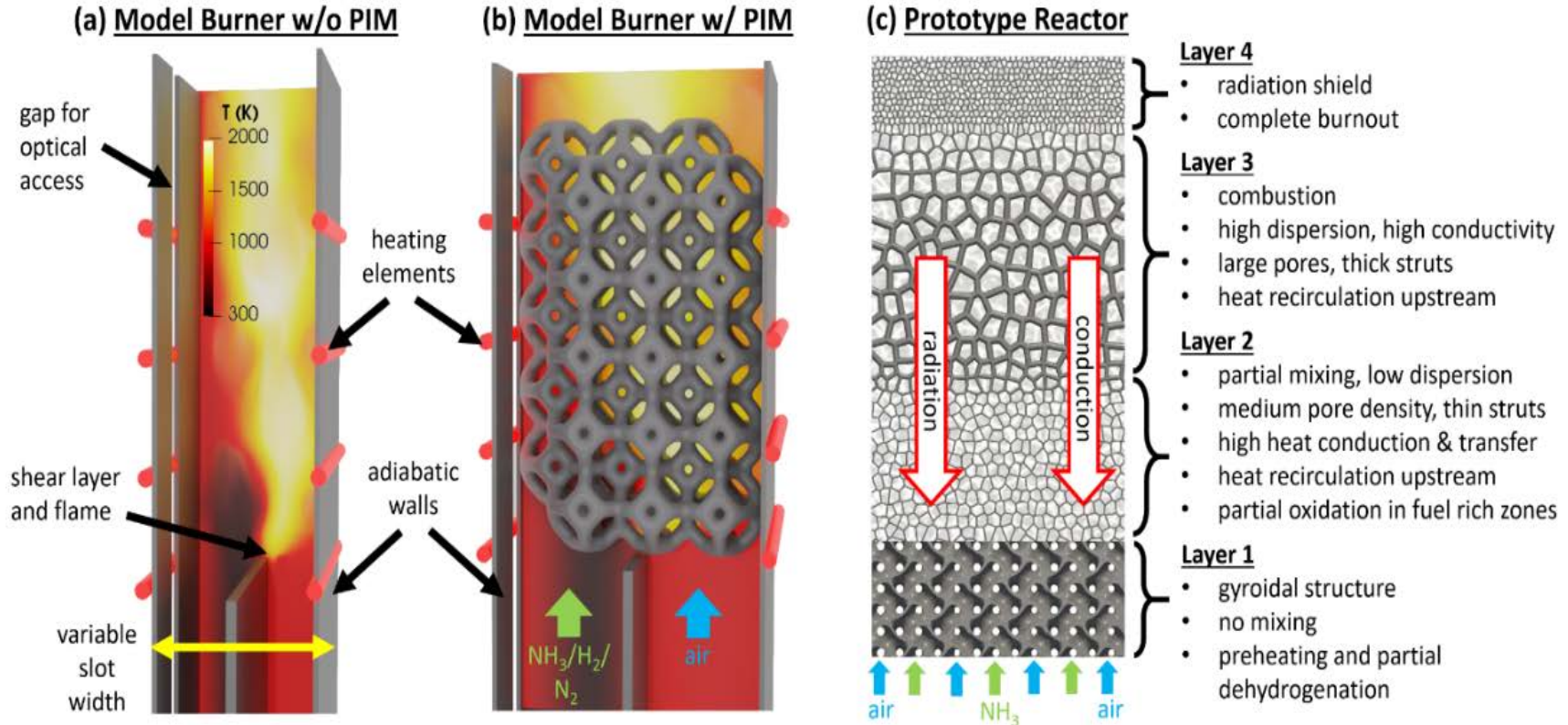




Ceramics **2023**, 6, 475–491.
<https://doi.org/10.3390/ceramics6010027>



Non-premixed ammonia combustion in tailored ceramic porous inert media



(a) Schematic model burner for fundamental studies of non-premixed NH_3 /air combustion without PIM.

(b) Model burner with PIM for basic system analysis

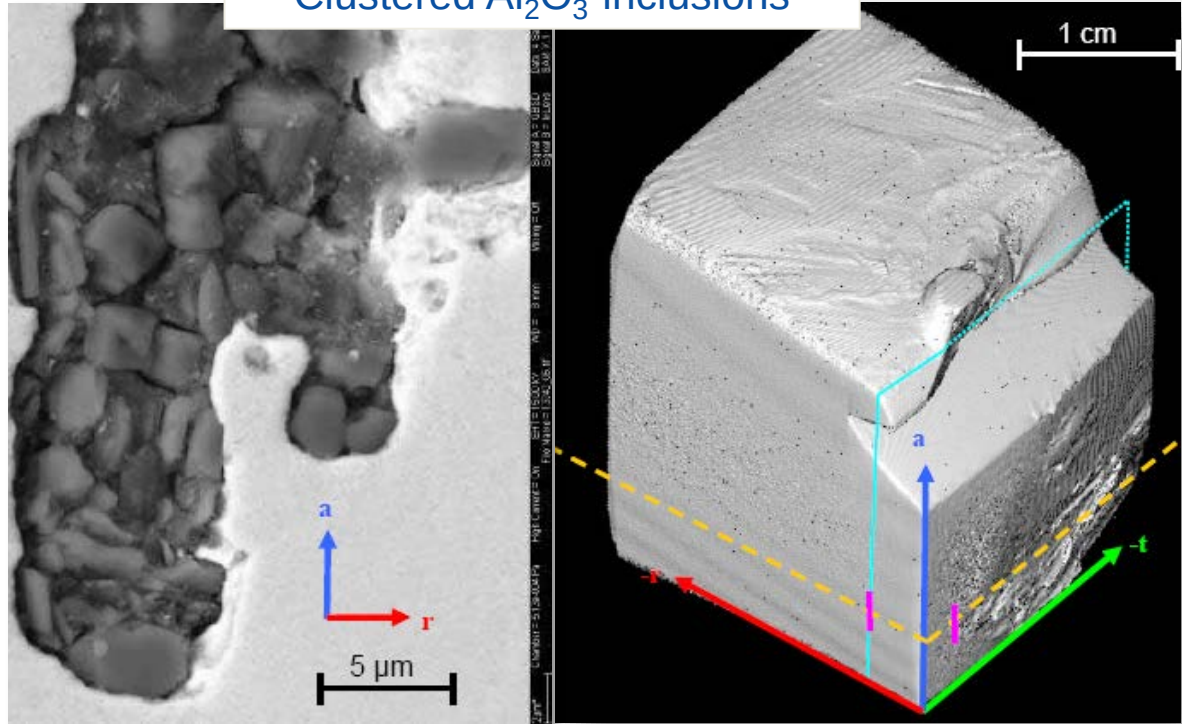
(c) Schematic prototype reactor with upstream gyroidal structures for NH_3 pyrolysis and downstream PIM for combustion and burnout (Figures not to scale), DFG 523876164, coordinator Prof. Trimis

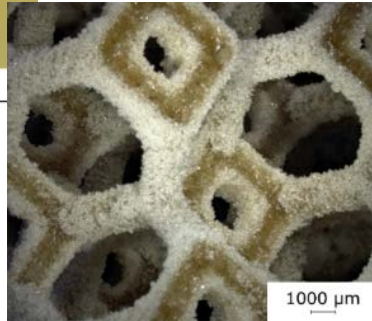
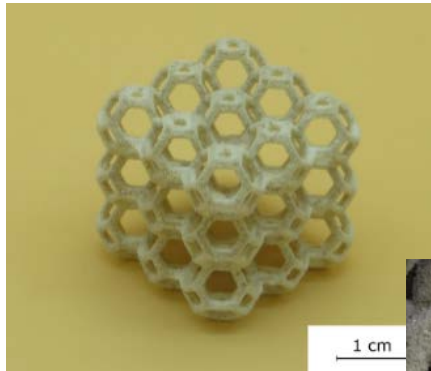
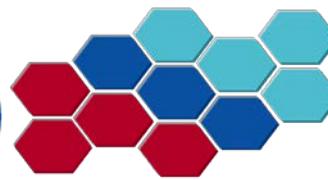


Small particles can stop a train...

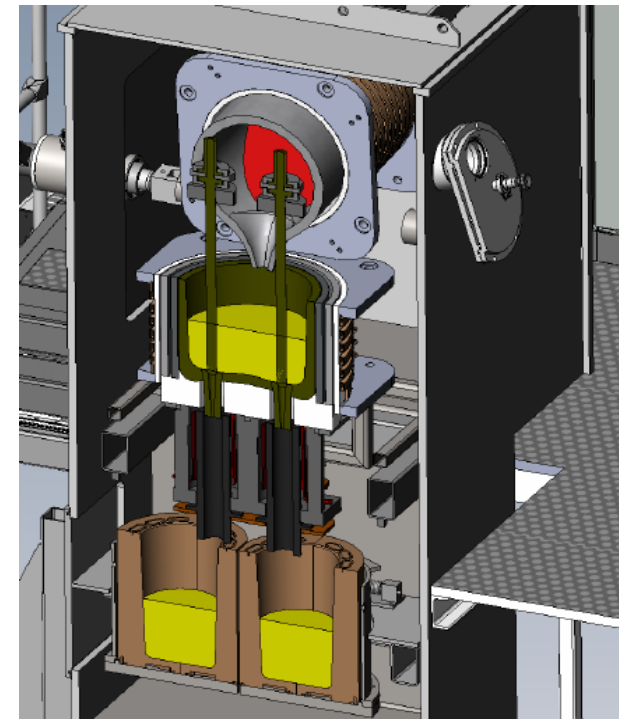
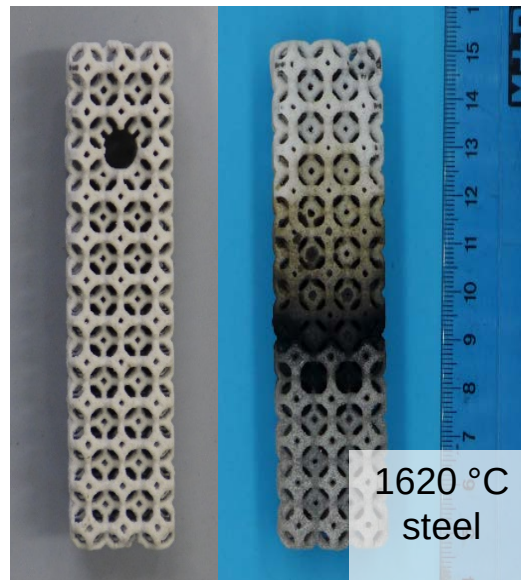


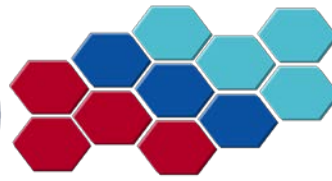
Clustered Al_2O_3 -inclusions



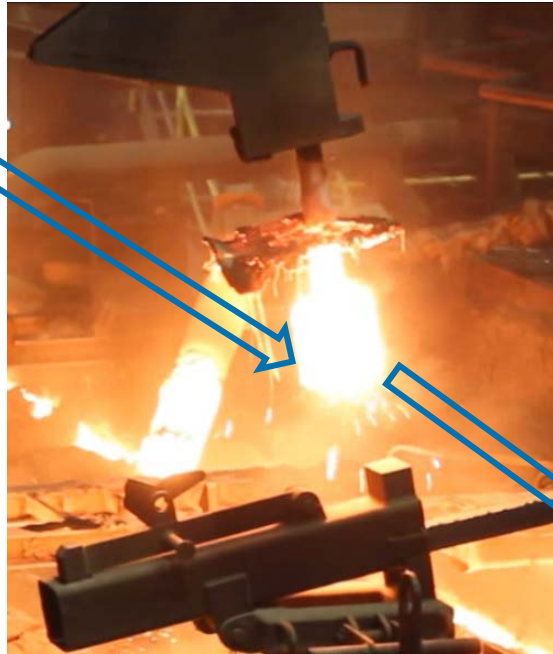


3D-sugar (SLS)
+
flame spraying



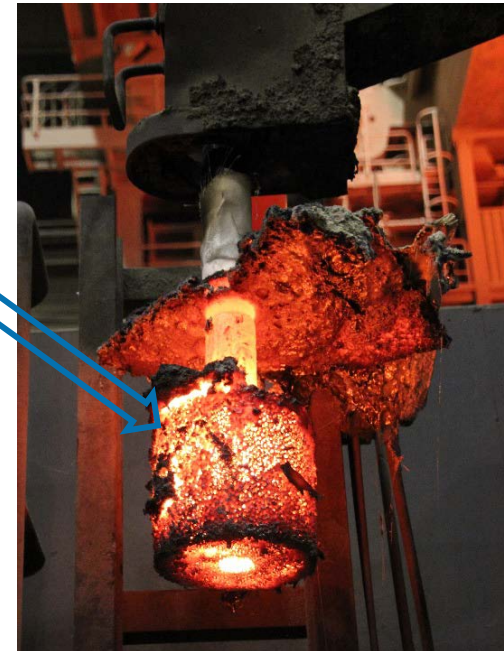


200 mm x 200 mm



Thyssenkrupp in Duisburg

Thyssenkrupp:
45 min
408 t steel melt





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Is there more potential?



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Refractory Recycling: A contribution for raw material-, energy- and „climate“- efficiency



- Worldwide 28 million tons of used refractory materials
- Main „use“ not in refractory applications
- Recycling of refractories in the range of 10 to 30 %
- CO₂-emissions due to their chemistry as well as due to their high temperature fabrication process



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We consume 2.5 kg MgO-C for one ton steel

**According to Worldsteel in 2021 approx. 1950 million tons steel
were produced worldwide**

**Via the H₂-Steel-Metallurgy we will consume at least
the same amount of MgO-C!**



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Specific CO ₂ -emission in t CO ₂ /t MgO	A	B
Raw material	Magnesite, Fe-rich	Magnesite, Fe-poor
Type of furnace and gas	Rotary kiln / nat. gas	Shaft kiln / nat. gas
Decarbonisation $\text{MgCO}_3 \rightarrow \text{MgO} + \text{CO}_2$	0.996	1.06
Direct calcination	0.349	0.591
Sum	1.344	1.655

Szednyj, I., Brandhuber, D.: Stand der Technik zur Kalk-, Gips
und Magnesiaherstellung Beschreibung von Anlagen in Österreich,
Umweltbundesamt 2007



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CORE Idea I – RECYCLING

Refractory Recyclates (MgO-C) + environmental friendly bio-binders

➔ bricks for steel ladles

CORE Idea II – UPCYCLING

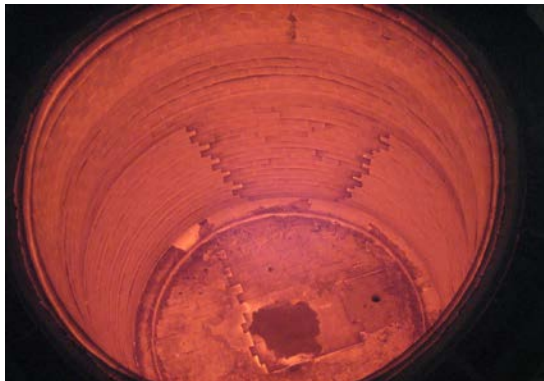
Refractory Recyclates (MgO) + Steel

➔ inert electrodes for the primary production of Al

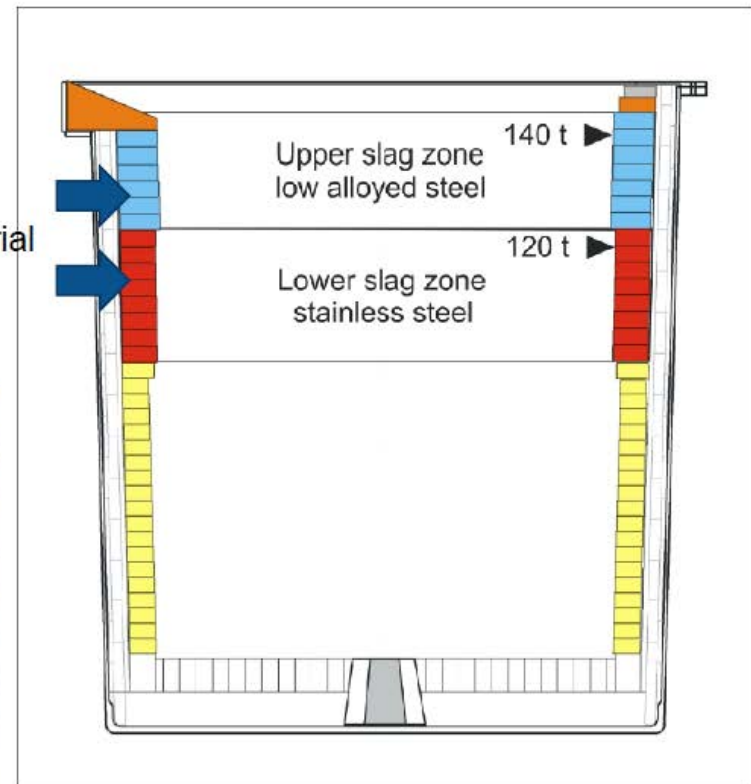
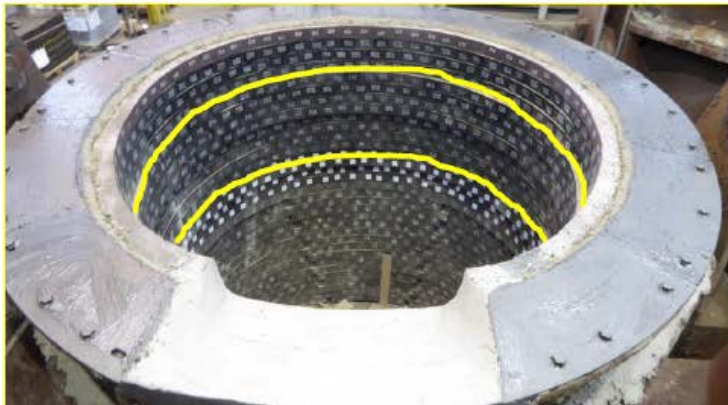


CORE Idea I - RECYCLING

DFG Transfer Project with DEW and Horn and today Refratechnik-Horn

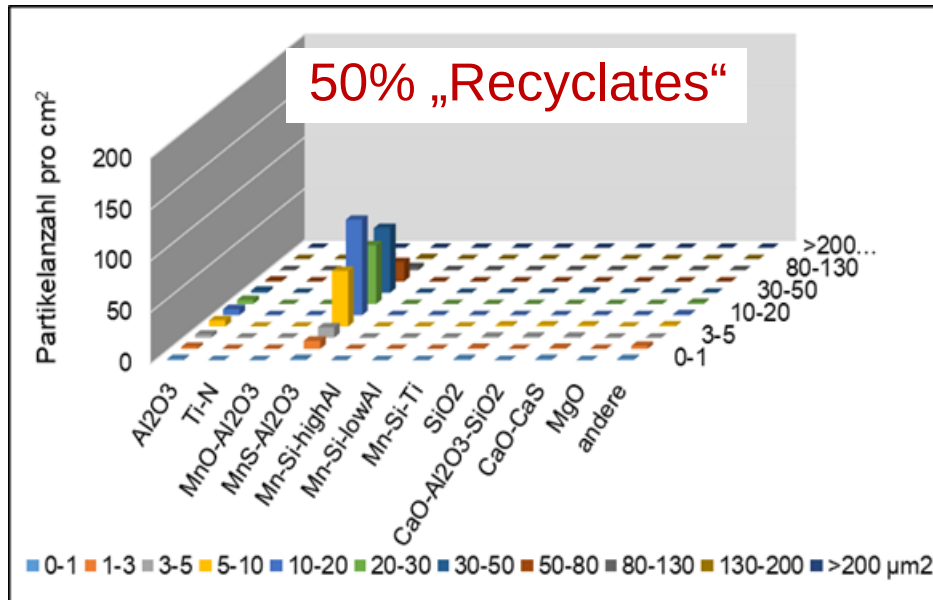
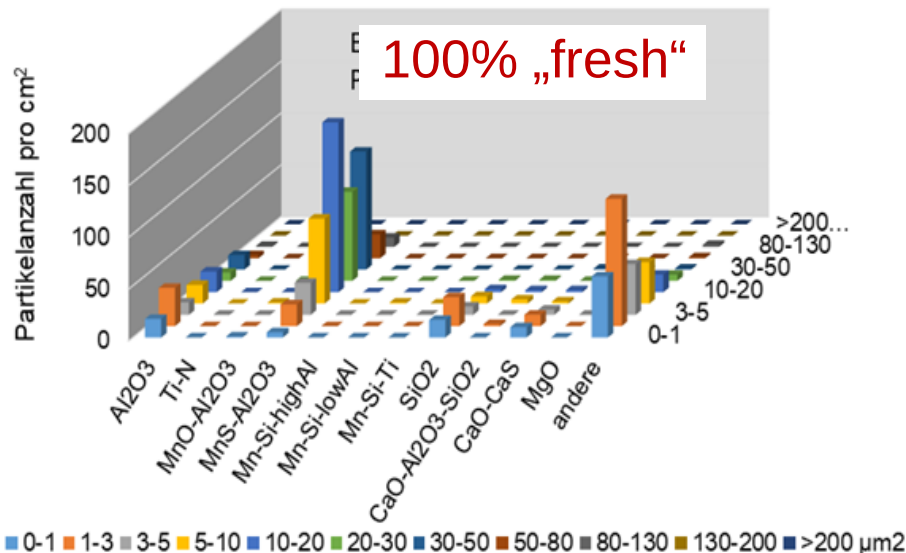


70% recycled material





CORE Idea I - RECYCLING

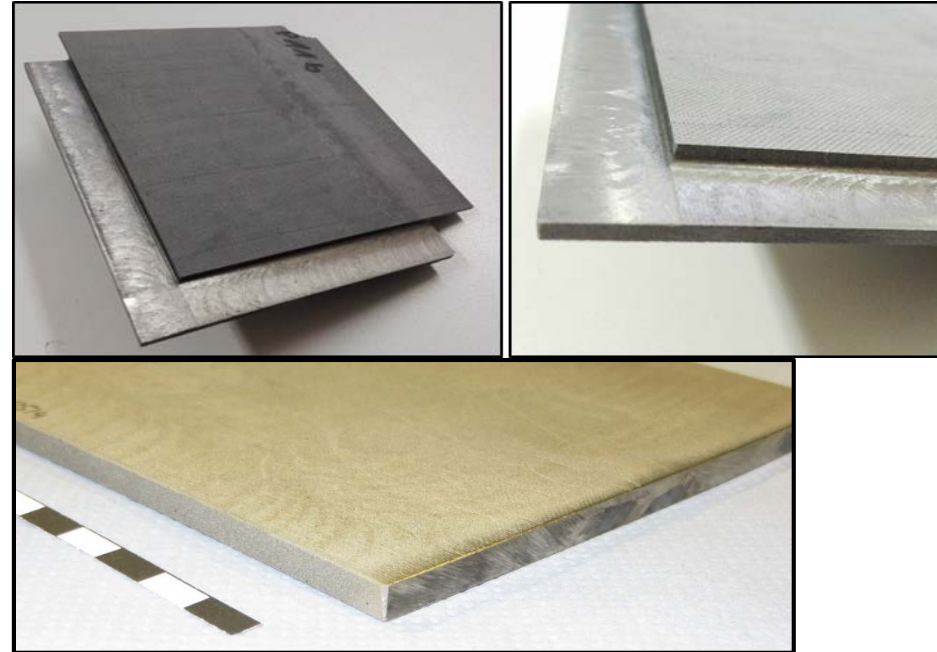




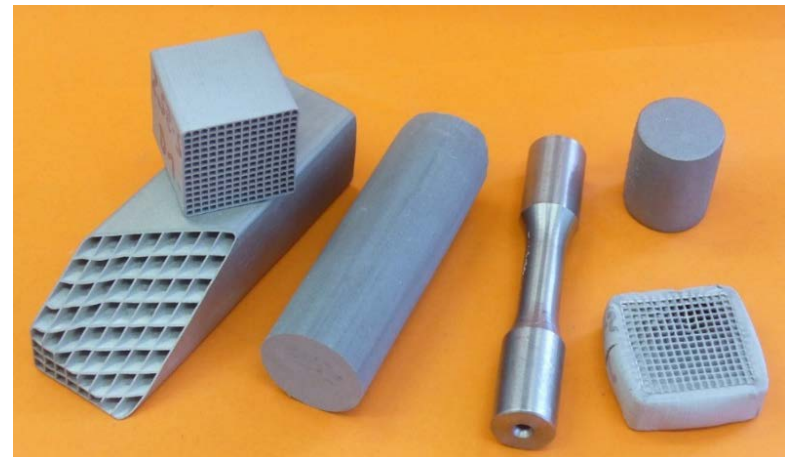
PM technologies – extrusion



Plastic Processing

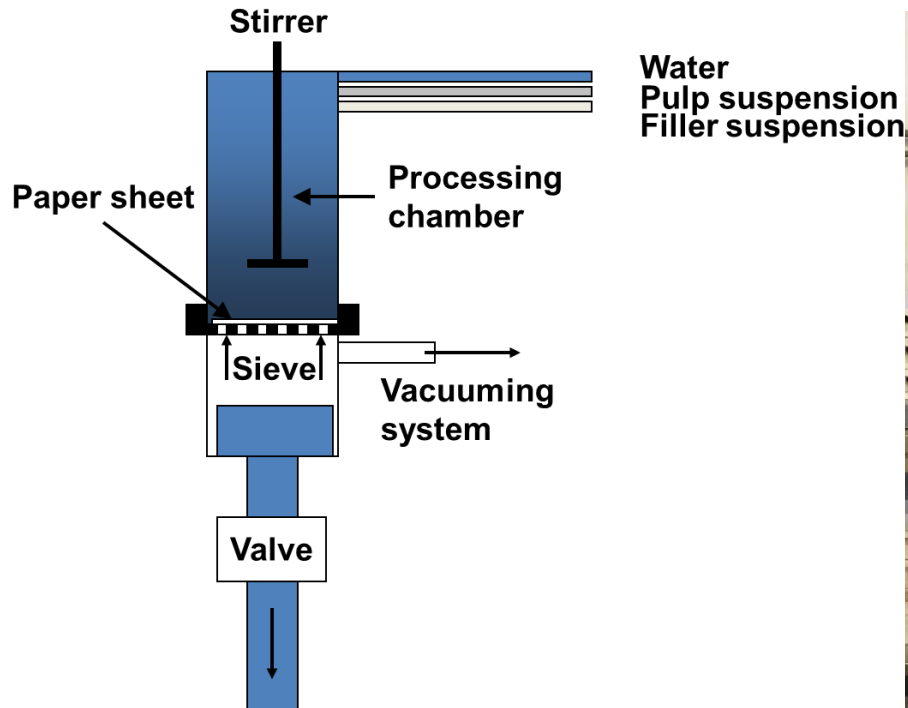


- **Ceramic-derived technologies enable large variety of material geometries**

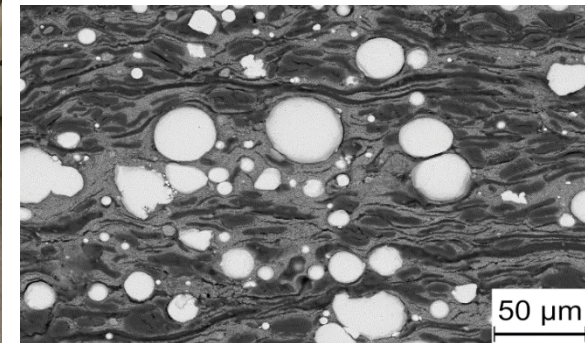
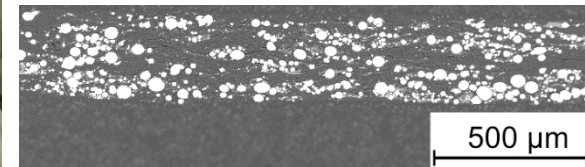




Paper manufacturing



PM technologies, paper-derived MMC



- Using process as used in paper production
- Inorganic fillers – steel / ceramic





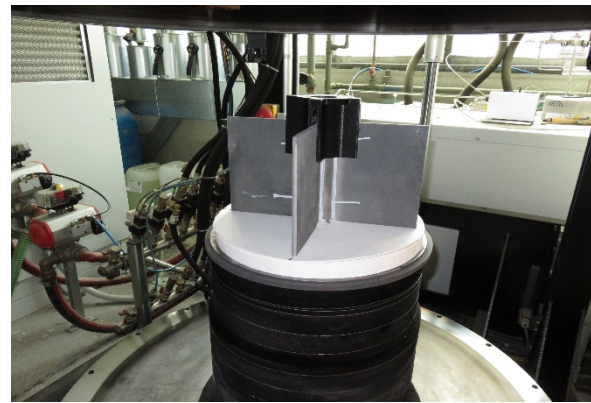
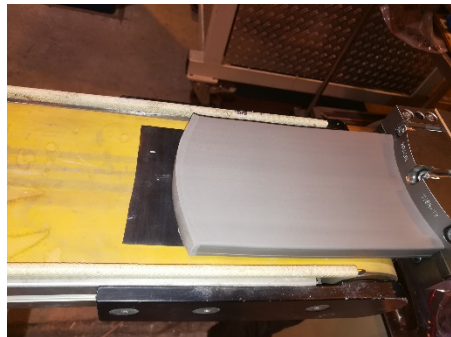
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Metal-Ceramic Composites for CORE Idea II



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Al-Melt-Applications: Heatable Stirrers

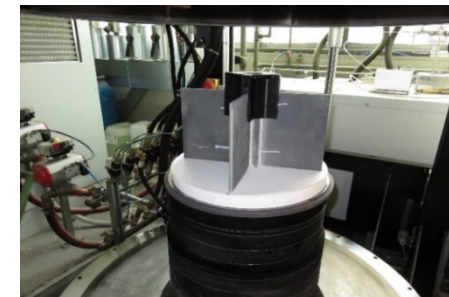
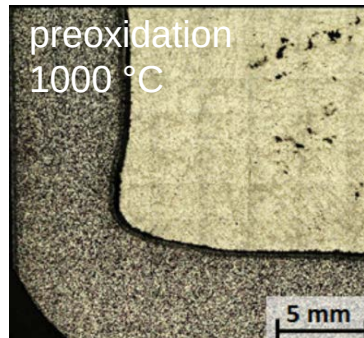
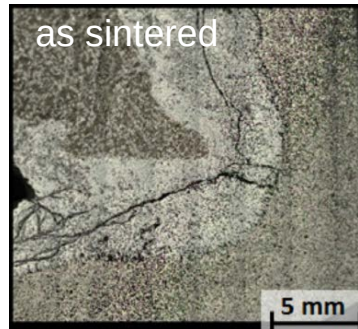


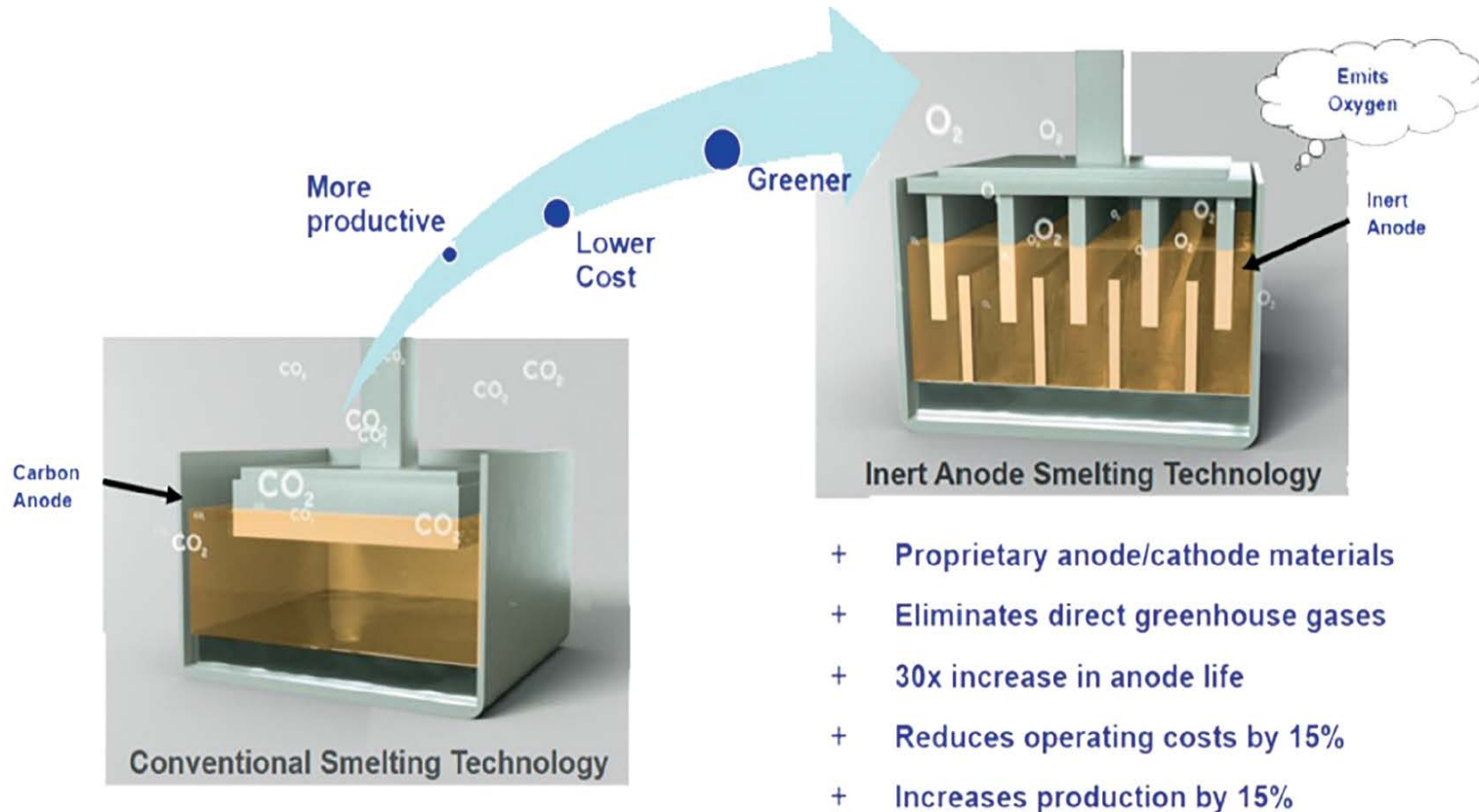


Metal-Ceramic Composites for CORE Idea II

Pre-oxidation at 1000 °C → very good corrosion resistance in **aluminum melts and in **cryolitic melts**!**

Stahl 316L+
40 Vol.% MgO
Sintering 1400 °C 2 h, Ar),
Pre-oxidation 4 h, air





„Elysis“, Alcoa, Rio Tinto, Apple with the Canadian State



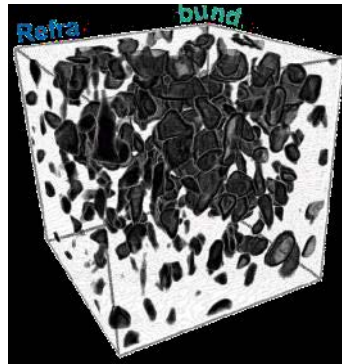
...based on the idea of the electrodes can we improve
the **thermal shock performance**
of alumina based refractories
for high temperature applications, in metallurgy- or in energy-plants...

Why Al_2O_3

The highest corrosion resistance in H_2 , NH_3 steam atmospheres!
(burners, lining materials, electrodes etc.)



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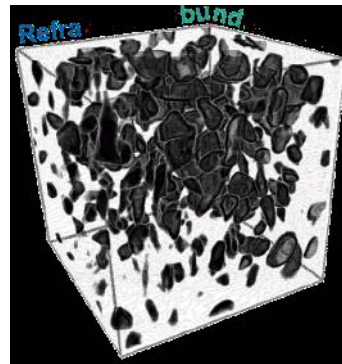


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REFRABUND

**Multifunctional, Coarse-Grained
Refractory Composites for Large-Scale
Key-Components in High Temperature Processes**



Functional coarse grains based on refractory composites **pre-sintered** for functional components

Refractory Composites
Nb with Al_2O_3

Granulate
Synthesis

Refractory Composites
Ta with Al_2O_3

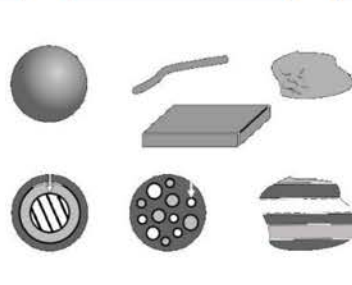
Castable &
Crushing

Extrusion &
Crushing

3D-printing

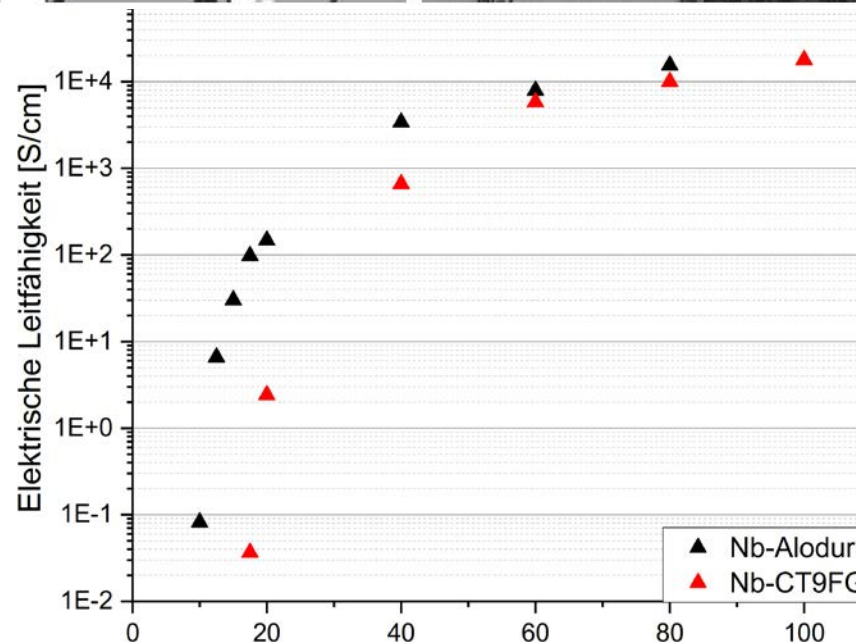
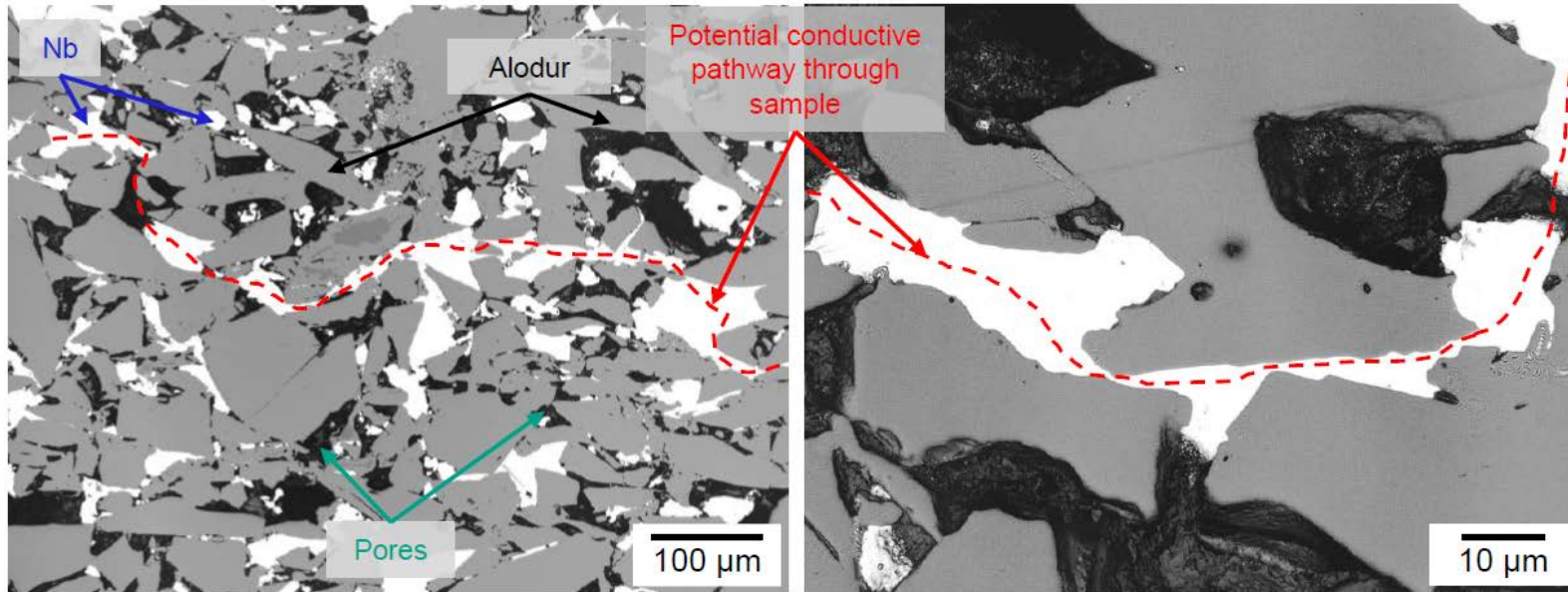
Alginate
Route

Granulation
via Pelletizing



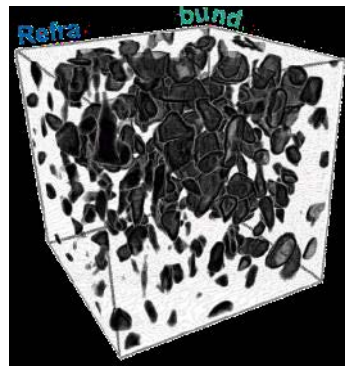
Raw material for coarse-grained prisms



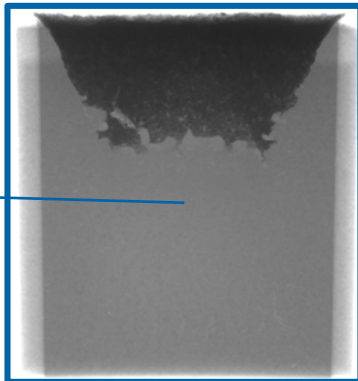
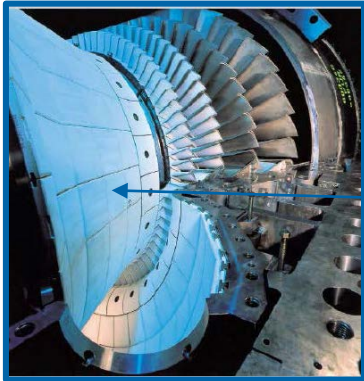




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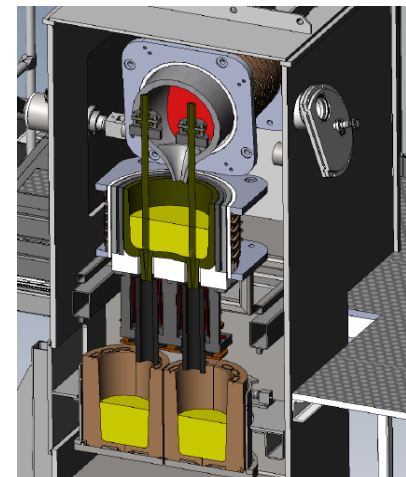
Heating Shields

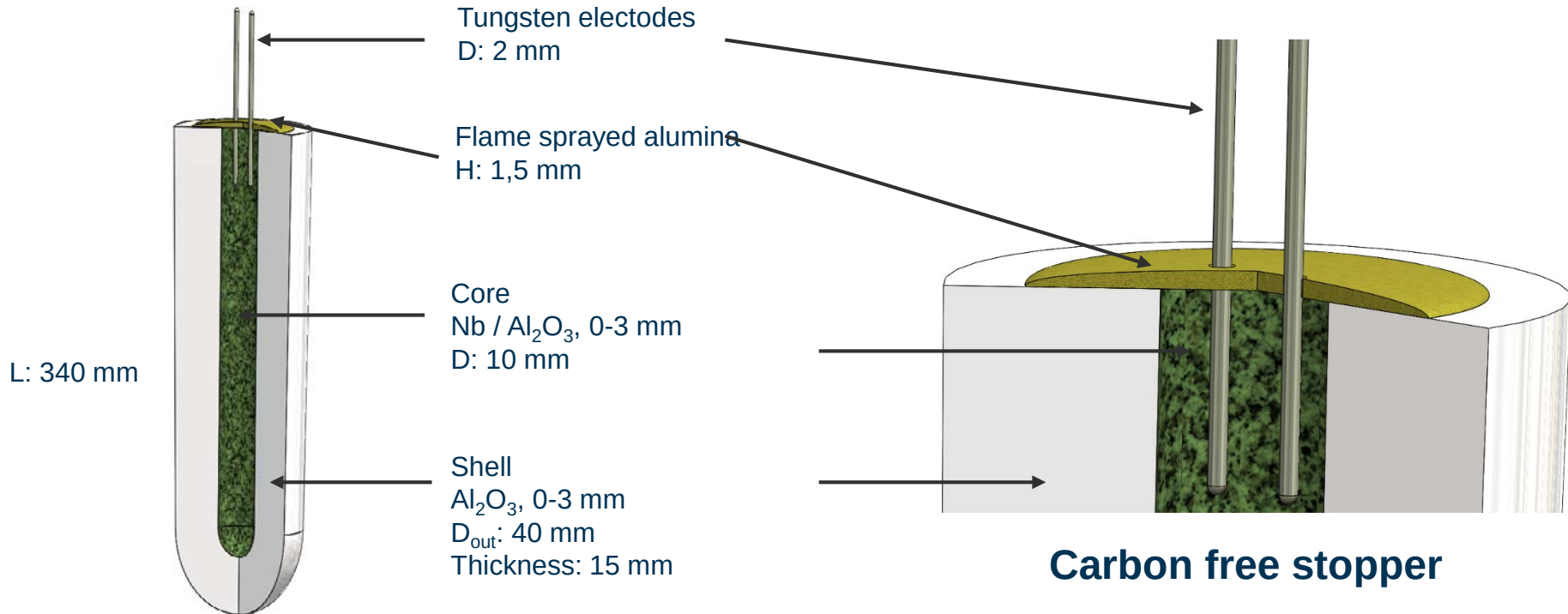
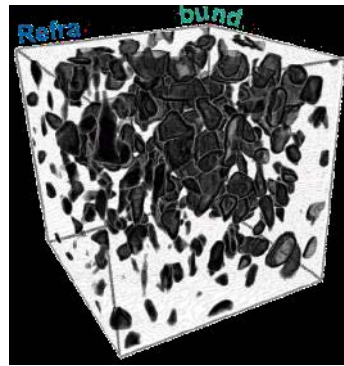
L: 200 mm
B: 185 mm
H: 30 mm



Stoppers

L: 340 mm
D: 40 mm





Aneziris, Gehre, Hubalkova et al.: Werkstoffverbund mit verbesserten Thermoschock- und Korrosionseigenschaften für Hochtemperaturanwendungen in der Metallurgie, in der chemischen Industrie und in der Zementindustrie,
Patentanmeldung DE 10 2022 001 073.9.



GREEN Technologies

❖ Microwave plasma torch...and more!



No cathode, which is consumed!.

No microwave coupling!

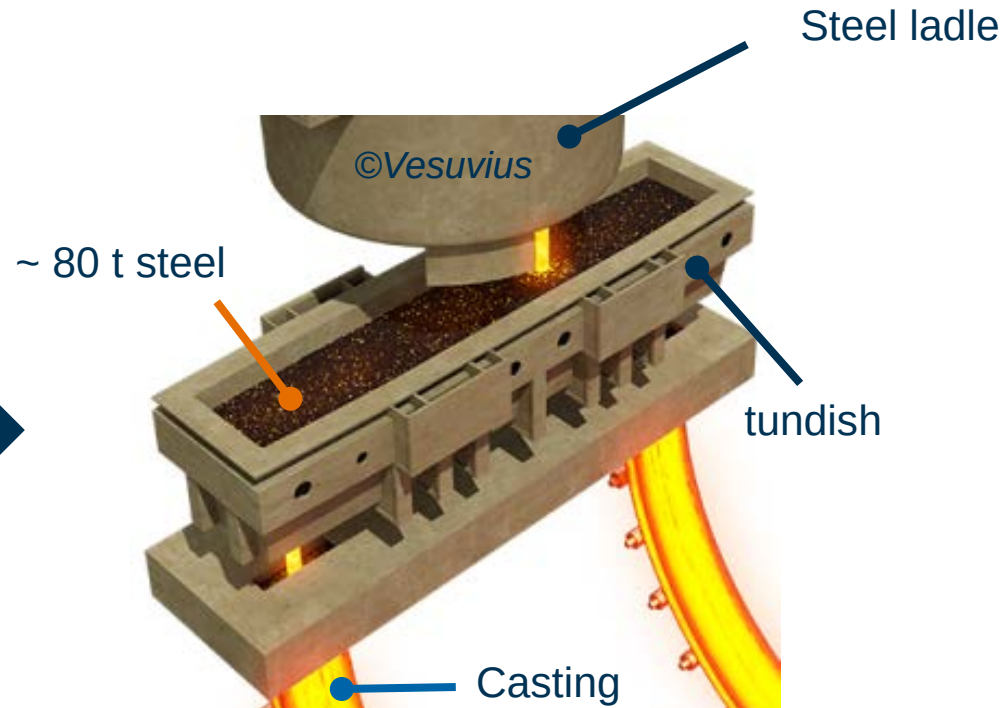


„Green hybride electrification“

Using core/shell electrodes
based on coarse grain refractory
composites

Using microwave plasma
burners

Pre-heating direct above the
casting machine;
no movement
of the tundish from
the gas preheating area



Patents {
DE 10 2021 004 675.7
DE 10 2022 001 073.9
DE 10 2022 122 280.2



Materials for
processes

Processing
of materials





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Refractories, Composites and Recyclates: Approaches for sustainability and strategic sovereignty

Thank you very much for your attention

<https://tu-freiberg.de/ikfww>



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WELTOFFENE
HOCHSCHULEN
GEGEN FREMDEN-
FEINDLICHKEIT



FAMILIE IN DER
HOCHSCHULE



Europa fördert Sachsen.
EFRE
Europäischer Fonds für
regionale Entwicklung