SAINT-GOBAIN

PERFORMANCE CERAMICS & REFRACTORIES

Fortgeschrittene 3D-Druck-Lösungen zur Reduzierung von Emissionen und Energieverbrauch in Brennersystemen

APRIL 24TH 2024

Dr. Matthias Schumann, ***Brad Nakanishi, Tom Briselden***

Saint-Gobain Performance Ceramics & Refractories

DKG Deutsche Keramische Gesellschaft e. V.

5. Freiberger FEUERFEST Symposium | 2024

SAINT- GOBAIN: A LEADING GLOBAL GROUP

Founded more than

350 YEARS AGO

Located in

75 COUNTRIES

Around

900

manufacturing facilities worldwide

Over

168,000

employees representing more than 110 nationalities

Sales in 2023

€47.9BN

More than

2,700

sales outlets

One of the top 100 **global innovators** over the last 10 years

World or European leader in most of our business

Commitment: **carbon neutrality in 2050**

4 consolidated Regions

Southern Europe, Middle-East, Africa

Northern Europe

Americas

Asia-Pacific

And one global entity

High Performance Solutions

HIGH PERFORMANCE SOLUTIONS

MOBILITY | LIFE SCIENCES | CONSTRUCTION INDUSTRY | ABRASIVES & COMPOSITE SYSTEMS | CERAMICS | ADHESIVES

over **48,000 EMPLOYEES**

over **300 PLANTS**

Over **5,500 employees**

in **50 plants**

Manufacturing sites in **10 countries**

SEFPRO

ZIRPRO

PERFORMANCE CERAMICS & REFRACTORIES

QUARTZ

CRYSTALS

NORPRO

SPECIALTY GRAINS & POWDERS

PCR

SAINT-GOBAIN

A UNIFYING PURPOSE: MAKING THE WORLD A BETTER HOME

4 STRATEGIC INNOVATION PRIORITIES

MAKING
THE
WORLD
A BETTER
HOME

NACHHALTIGKEIT

2050 NET ZERO CARBON

A decarbonated home

More performance with less

A better living for all

Recognized commitments

CDP A LIST 2022 CLIMATE

Bloomberg Gender-Equality Index 2023

top EMPLOYER GLOBAL 2023

BURNER SYSTEMS – ENERGY EFFICIENCY NEED

- **Strong impact on production cost & energy efficiency of equipment**
- **Responsible for direct & indirect costs related to heating**
  (e.g. price of fuel, taxes of emissions)
- **Strive for improvement of industrial heating**
  - Fuel adjustment
  - Burner system adjustment
  - Burner material adjustment (e.g. metal ⇔ ceramic(s))
- **Higher efficiency with higher flame temperature ?**
  - Switch from metal to ceramic material
- **Iron & Steel industry on first row !**
  - One of the strongest participants in energy consumption & CO_2 emissions

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CHALLENGES AND OPPORTUNITIES FOR STEEL REHEATING

Typical Continuous galvanizing / annealing lines operate at 30 – 50% Heating efficiency

0,92 GJ/t
50 kg-CO_2e/t
[1]

0.42	Strip (product)
0.28	Flue stack
0.22	Other thermal leaks

X 33 Mt [2] = 8,3 TWh/y
1,7 Mt-CO_2e/y

Additional challenges:

- Product quality / Heating uniformity
- Maintenance
- Fuel costs
- NO_x and emissions regulations
- Throughput

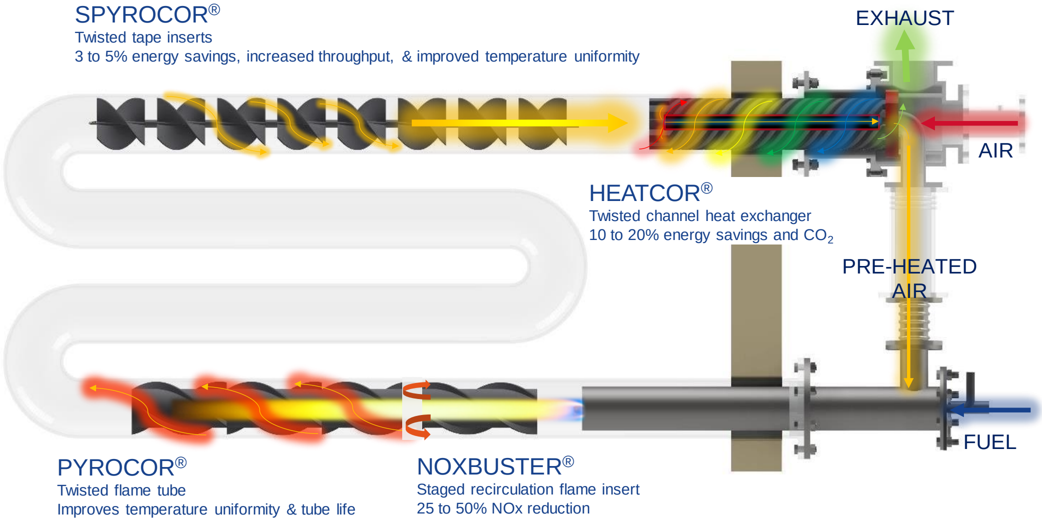
[1] S. Sundaramoorthy et al. *Energy Eng.* (2016).
[2] "2022 AIST North American Galvanizing Lines Roundup." *Iron & Steel Technology*. (2022).

CERAMIC INSERTS FOR IMPROVING COMBUSTION HEATING

AMASIC-3D®
Commercially available concepts:

- Nozzles
- Recuperators
- Nox reducing inserts
- Twisted tape inserts
- Etc.

- Up to 70% less NO_x
- Up to 30% less energy
- Up to 30% less CO_2
- Enhanced tube temperature uniformity
- Reduced maintenance
- Higher throughput



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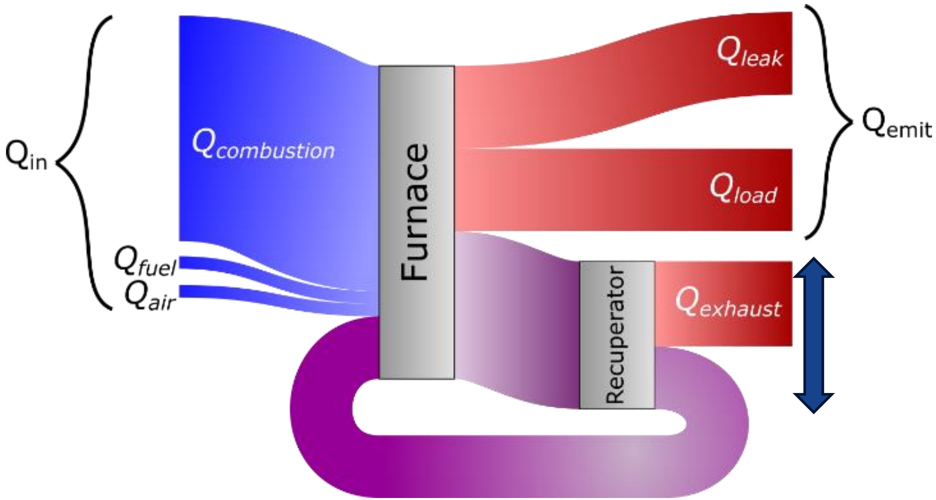
MITIGATING ENVIRONMENTAL IMPACTS FROM COMBUSTION HEATING

Thermal efficiency

Heating $\eta_{heating} = \eta_{LHV}\eta_{furnace} = \frac{Q_{load}}{Q_{in}}$

Combustion $\eta_{LHV} = \frac{Q_{emit}}{Q_{in}} = 1 - \frac{Q_{exhaust}}{Q_{in}}$

Furnace $\eta_{furnace} = \frac{Q_{load}}{Q_{emit}}$



Effective solutions:

1. Increase $\eta_{furnace}$ by enhancing energy transfer to strip / increasing Q_{load}
2. Increase η_{LHV} by improving recuperator efficiency
3. Mitigate NOx emissions from higher η_{LHV}
4. Minimize thermal losses to walls, etc. Q_{leak}

LVH: lower heating value

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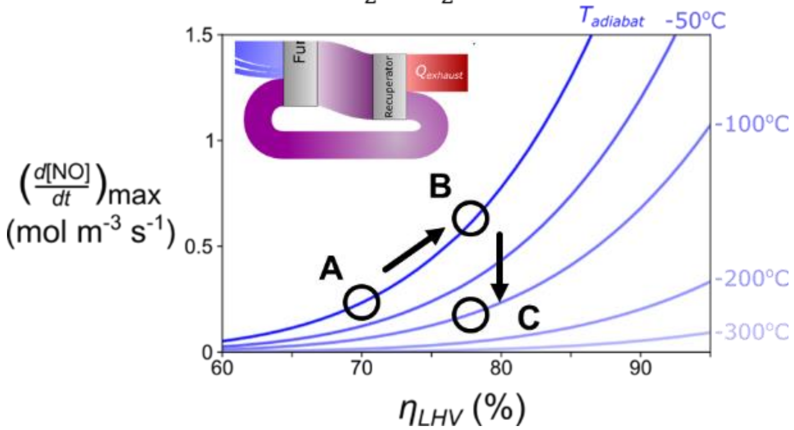
NOX – ENERGY SAVINGS TRADEOFF

NOx *usually* increases with combustion efficiency for recuperated systems because higher efficiency recuperators increase preheat air temperature

$$O_2 + N_2 = 2NO$$

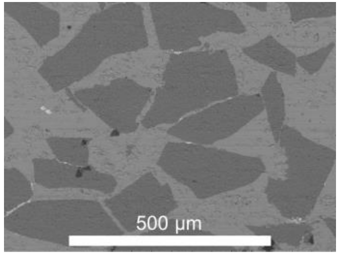


Approaches mitigating hot spots → **NOx reduction by 50+%**

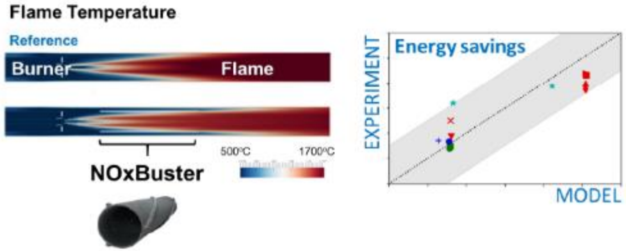
SAINT-GOBAIN TOTAL BURNER SOLUTIONS – AMASIC-3D®

Retrofit, advanced thermal ceramic designs

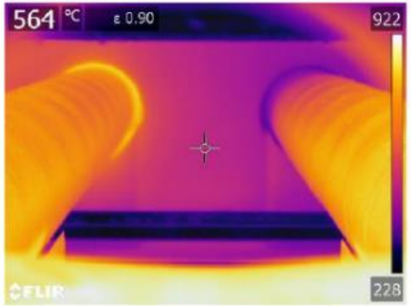
- Additively manufactured designs in robust SiC

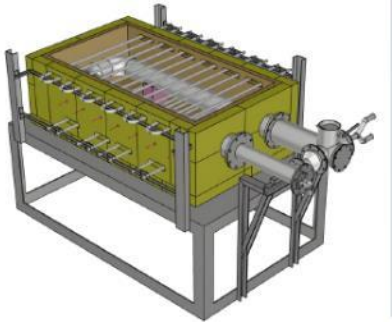


- Expert numerial simulations / optimization capabilities



- Specifically adapted testing competencies





- Solutions tailored to requirements: energy savings, NOx reduction…

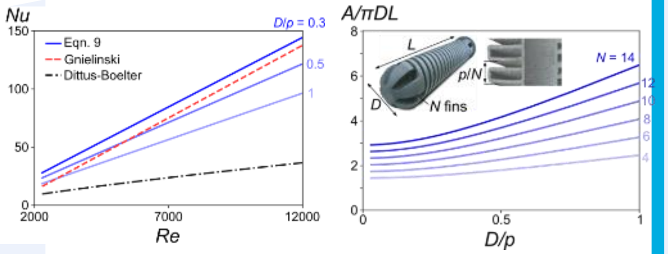
CERAMIC INSERT CONCEPT

HEATCOR®

- improvement of combustion efficiency η_{LHV} of up to 20%

-3-4x convective heat transfert

-2-6x surface area via regular metal plug recuperator

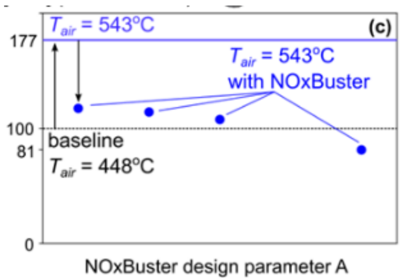


NOXBUSTER®

- additional control of flame mixing

- reduction of local flame temperature

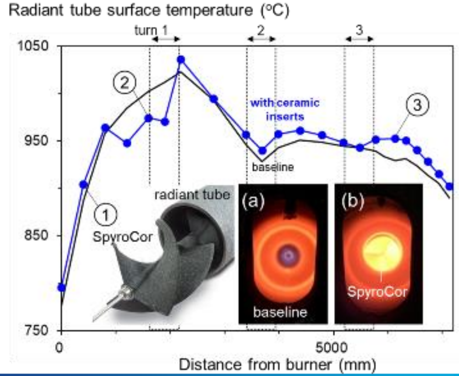
- tailored design for different burner layout



SPYROCOR®

- allowing increased furnace efficiency $\eta_{furnace}$

- improved heat transfert



MODELISATION & FIELD CONFIRMATION – POSCO STEEL

Continuous annealing furnace @ Posco South Korea

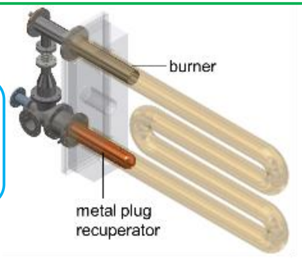
	Energy consumption	NOx emission rate	η_{LHV}	$\eta_{furnace}$	$\eta_{heating}$
Baseline			70%	53%	37%
Trial A SpyroCor HeatCor v1	-17%	+127%	81%	56%	45%
Trial B SpyroCor HeatCor v2 NOxBuster v1	-11%	+3%	75%	56%	42%
Trial C SpyroCor HeatCor v2 NOxBuster v2	-11%	-33%	75%	56%	42%

- performance trials @RIST

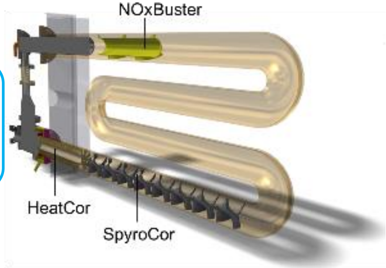
- energy consumption & Nox emission rate

- finetuning of NOx emissions with adjusted design of NOXBUSTER®

Initial configuration



Developed configuration



MODELISATION & FIELD CONFIRMATION – POSCO STEEL

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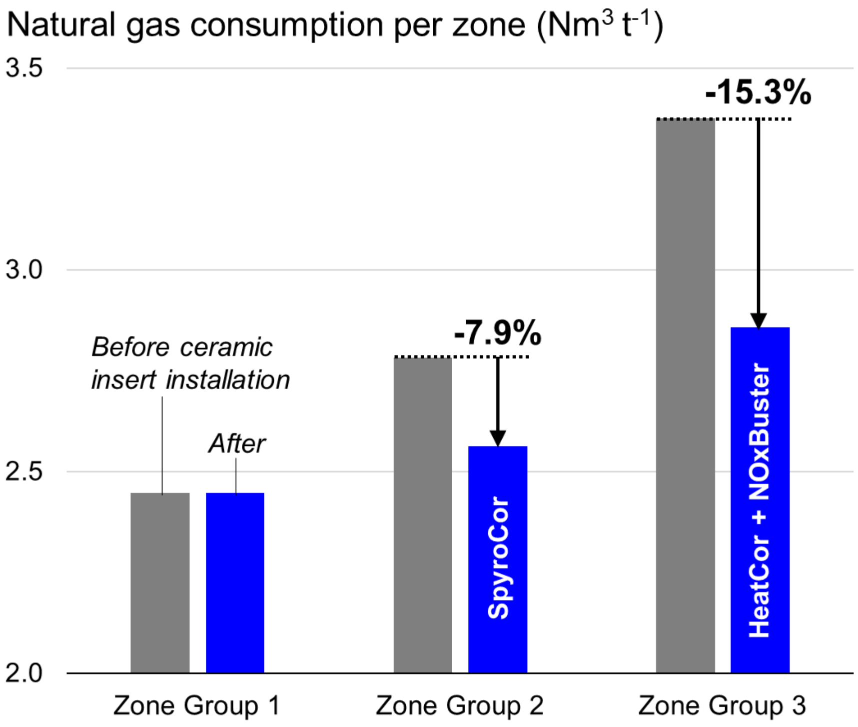


- real case : annealing furnace configuration @Posco South Korea

- 8 zones, 88 RT's, air-staged burners rated for 170 kW (0.58 MMBTU/h)

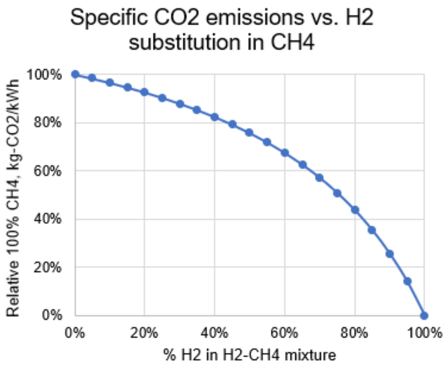
- 4x zones with SpyroCor only: 7.9% less energy

- 1x zone with HeatCor + NOxBuster: 15.3% less energy + 17% less NOx

➔ Anticipated combined performance: >20% less energy and 17% less NOx

COMBUSTION ENERGY & EMISSIONS – H2 IMPACT

Use of natural gas / H2 mix up to 20% usual in combustion systems
- ➢ no or no significant impact on combustion efficiency and modification of existing combustion system
- ➢ low impact on CO2 emission with if low substitution rate
- ➢ possible to adjust heat intake through gas volume and temperature



TBS Amasic-3D® system / ceramic insert suitable to enhance enhance use of H2 burning:

➢ initial computations for industrial burner-radiant tube configuration confirms **flame temperature increases for H2** use
- ➔ **NOxBuster®** efficient in NOx emission reduction

➢ H2 combustion impacts **air/fuel and exhaust/flow ratios**
- ➔ **HeatCor** ® may be designed for optimal recuperator performance (pressure, energy recovery)

➢ H2 combustion **reduces exhaust flow (convection) and reduces CO2(g) concentration** (radiation)
- ➔ **SpyroCor** ® for enhanced heat transfer and efficiency

COMBUSTION ENERGY & EMISSIONS – H2 IMPACT

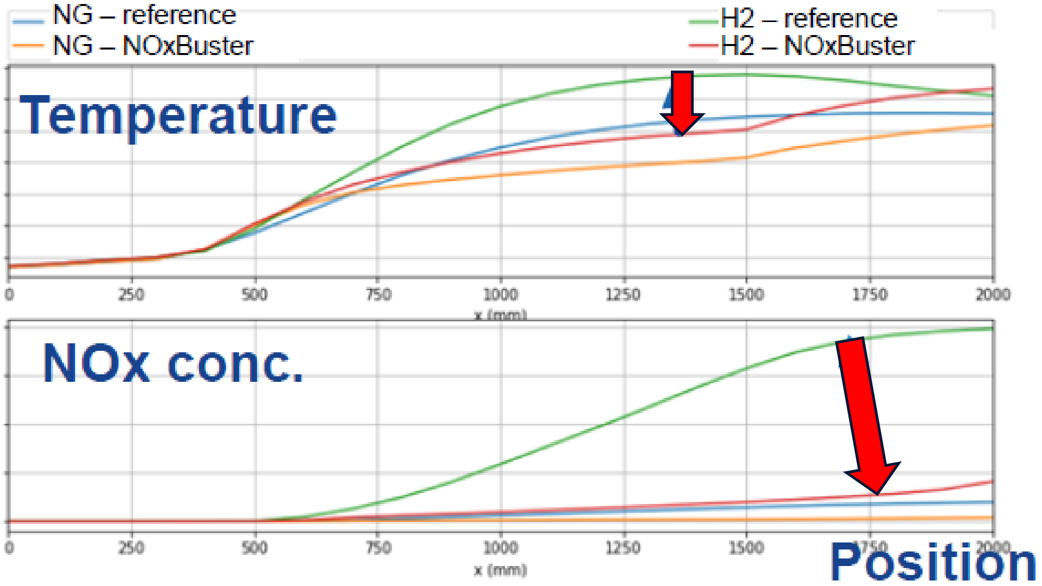
Simulation of impact of ceramic inserts

Hydrogen (H2) ⇔ Natural gas (CH4) performance differences

➔ air-combustion, equivalent firing rate

Adiabatic flame temperature / °C	+165°C
Fuel flow (v/v)	3.32x
Air flow (v/v)	0.83x
Exhaust flow (v/v)	0.91x
Stoich. Air:Fuel	9.56 → 2.39
Stoich. Exhaust:Air	1.10 → 1.21
CO2(g) conc.	9% → 0%
H2O(g) conc.	19% → 35%

➔ Possible to improve temperature filed & NOx emissions through Ceramic inserts



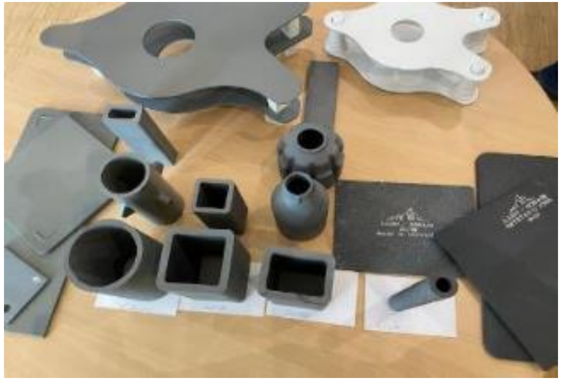
COMBUSTION ENERGY & EMISSIONS – H2 IMPACT

Material challenges

- ➢ Combustion atmosphere relatively easy to control
- ➢ Adapted H2 design for combustion materials relatively easy to develop
    - H2 rich & H2O rich atmosphere
- ➢ … suitable & reliable ceramic material to provide by ceramic manufacturers (furnace linings as well as burner systems)

- Need for more detailed dive into ceramic material under H2 atmosphere
- Association needed with users / burner OEM / furnace OEM
- Develop suitable testing devices

- Confirmation on limits for use of existing (SiC) burner material or which need to develop new material

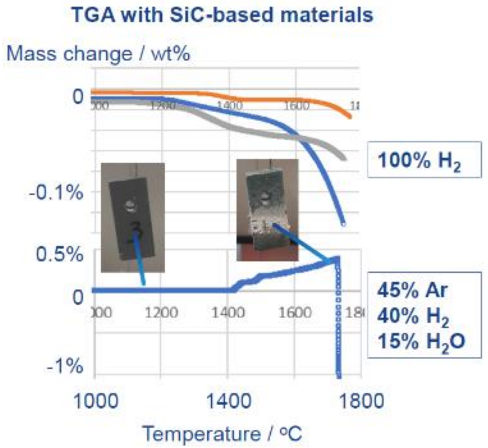


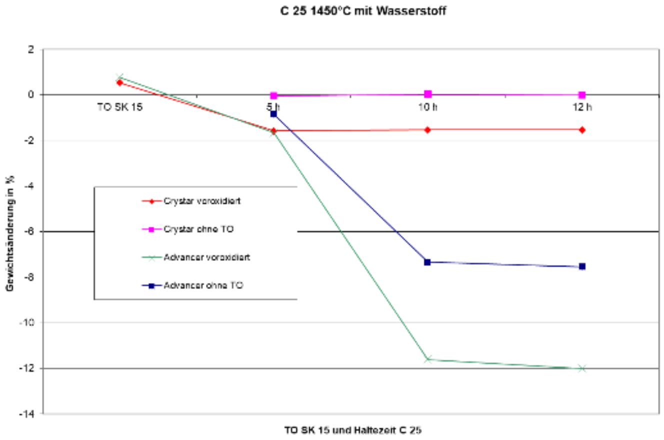
COMBUSTION ENERGY & EMISSIONS – H2 IMPACT

Material challenges

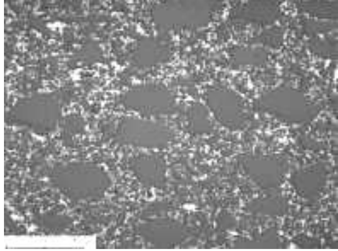
- Ceramic burner materials made out of SiC (sinterered, recrystalized, siliconized, nitrate bonded) or oxyde materials

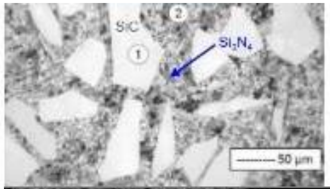
- SiC burners:
  - Preliminary lab scale results indicate SiC has wide ranging thermal stability in H2 rich and H2O rich atmospheres
  - H2O level & SiO2 layer to understand as impact on material stability

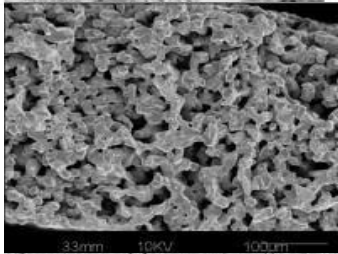


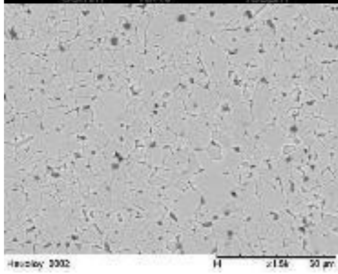


Kiln kinetics:
- Oxiziding zone:
  SiO2 built-up
- Reducing zone:
  - SiO2 destruction









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COMBUSTION ENERGY & EMISSIONS – H2 IMPACT

Understanding material behavior

- Get inspired from science & operational observations
- @ high temperature (>1200°C) SiC thermodynamically unstable in pure H2 (decomposition starting)
- SiC stable in high moisture H2 environment thanks to protective SiO2 layer

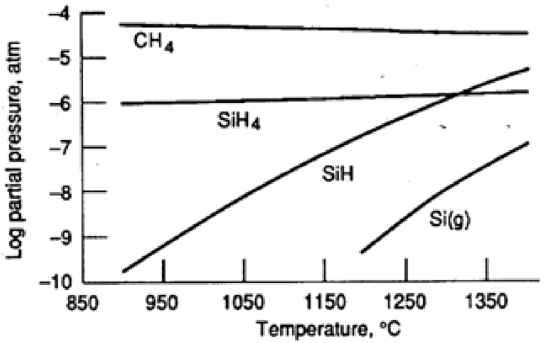

Figure 1-Equilibrium partial pressures of reaction product gases for reaction of SiC with pure H_2 at 1 atm.

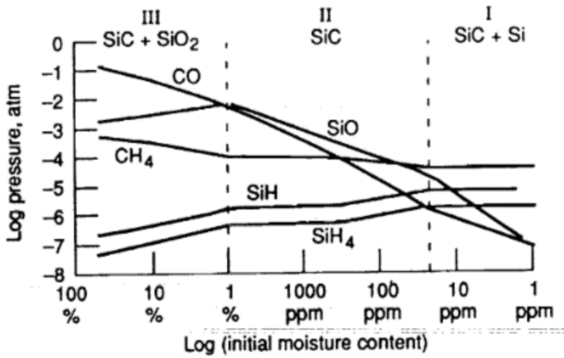

Figure 2-Stability of SiC in $H_2 + H_2O$ at 1 atm and 1400°C.

T. Herbell, A; Eckel, D. Hull: Fall Meeting Metallurgical Society, 1990

SUMMARY & CONCLUSION

- Energy saving and reduction of NOx emissions possible using SiC ceramic inserts in burner components
- Efficient simulation and design adjust to maximize saving effect
- Amasic-3D® combination of material & design for optimize results

….Going beyond:

- switch from natural gas to H_2 big challenge for all materials in the heating process (metals & ceramics)
- Need of understanding of material behaviour in H_2 environment
- ceramics (e.g. SiC) offer unique product properties in challenging combustion environments but not yet optimized
- Common interest of ceramic suppliers, furnaces users, furnace OEM and burner OEM

Herzlichen Dank für Ihre Aufmerksamkeit !

THANK YOU

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