SiC foams for high temperature applications

Alberto Ortona*

University of Applied Sciences (SUPSI), The iCIMSI Research Institute, Galleria 2, CH 6928, Manno, Switzerland

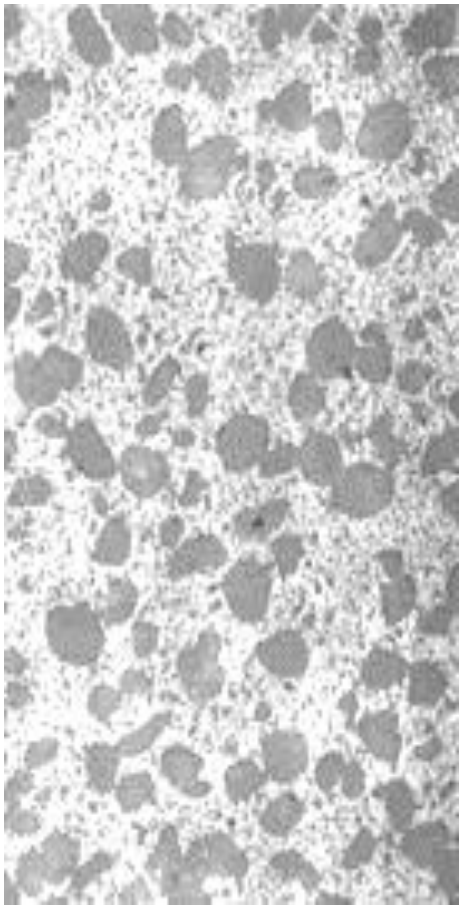
Sandro Gianella, Daniele Gaia

Erbicol SA, Viale Pereda 22 P.O. Box 321, 6828, Balerna, Switzerland

Outline

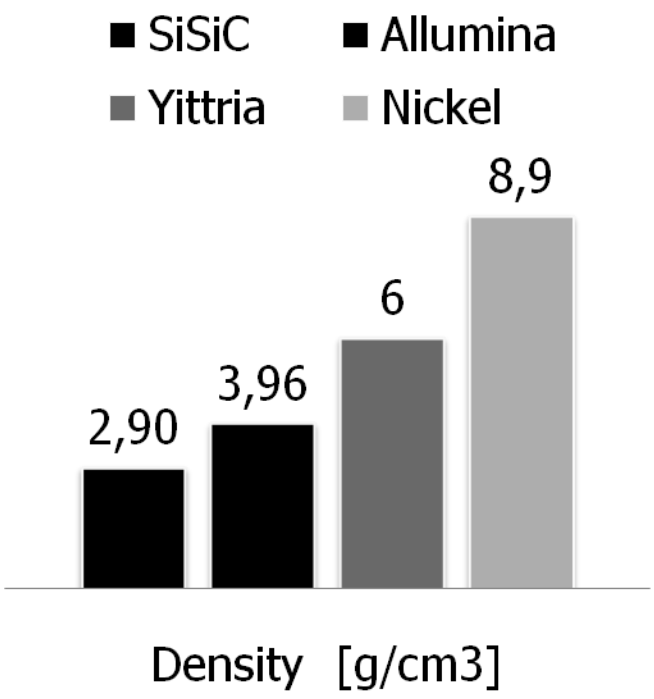
- Why Si SiC bulk material ?
- Why Si SiC reticunlated foams ?
- Si SiC foams aplications
  - Porous Burners
  - Reformers
  - Catalytic supports
  - Solar absorbers
  - Mechanical applications

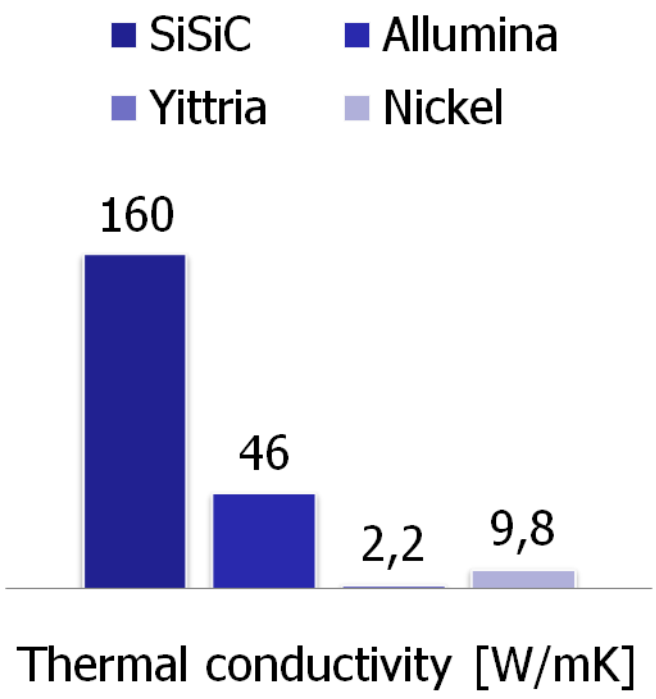
Why Si-SiC?



Porosity	0%
Tensile Strength, Ultimate	400 MPa
Modulus of Elasticity	350 GPa
Compressive Yield Strength	2000 MPa
Poissons Ratio	0.24
CTE, linear at room Temperature	4.30 µm/m-°C
Specific Heat Capacity at room Temperature	1.10 J/kg K

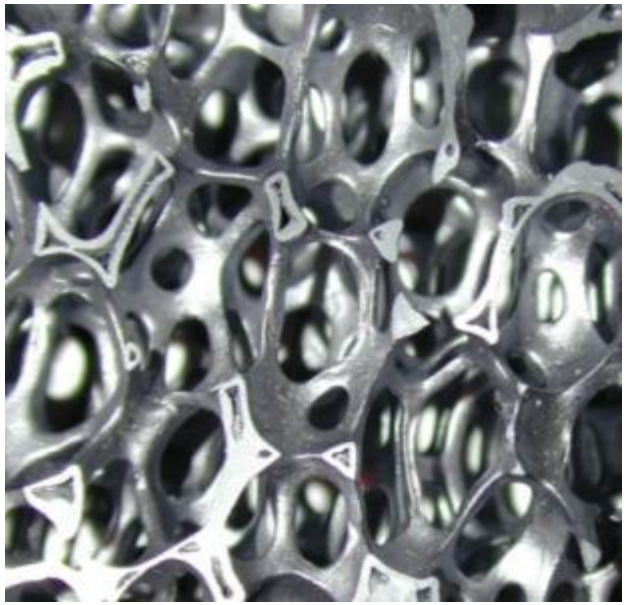
Why Si-SiC?


SiSiC
Allumina
Yittria
Nickel
2,90
3,96
6
8,9
Density [g/cm3]

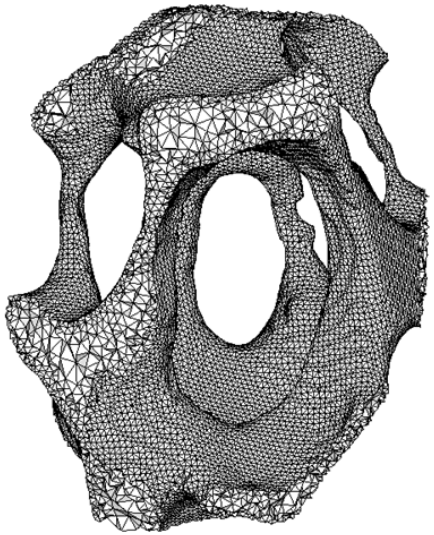

SiSiC
Allumina
Yittria
Nickel
160
46
2,2
9,8
Thermal conductivity [W/mK]

Macroporous reticulated Si-SiC foams

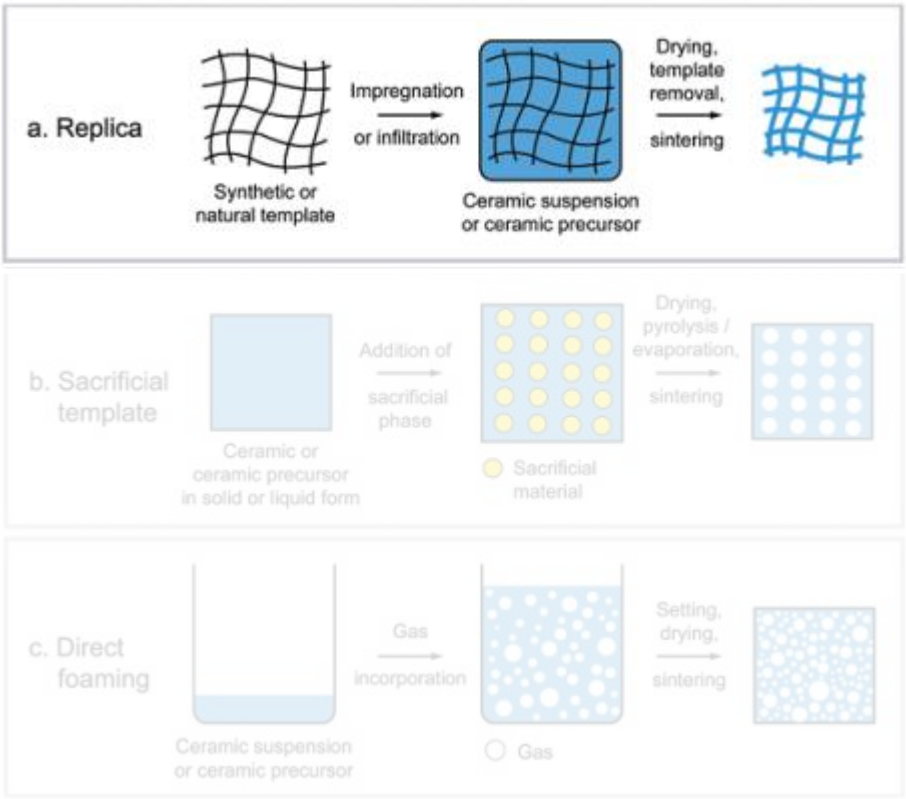
Macroporous reticulated Si-SiC foams



4mm



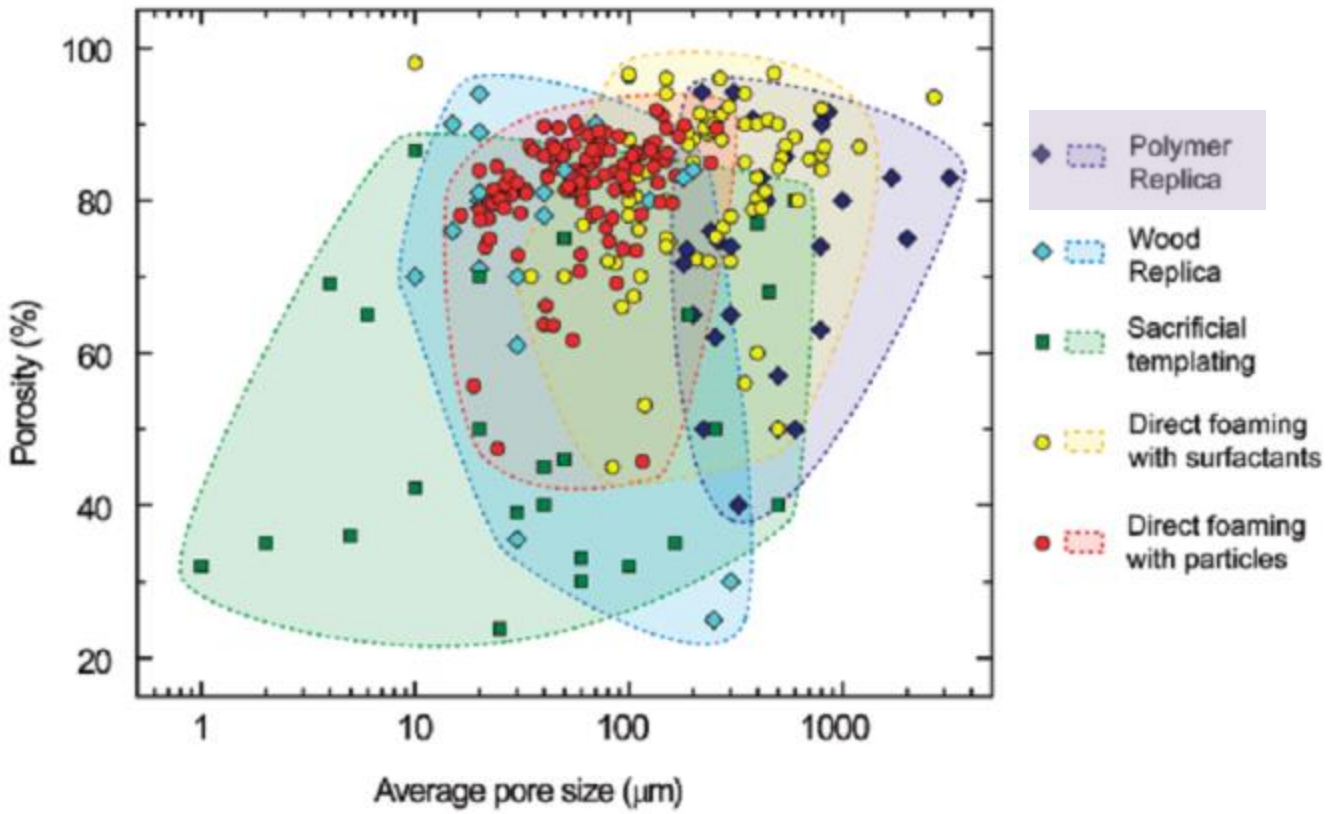
Si-SiC foams manufacturing



R. Studart, U. Gonzenbach, E. Tervoort, L.J. Gauckler "Processing Routes to Macroporous Ceramics: A Review" J. Am. Ceram. Soc., 89 [6] 1771–1789 (2006)

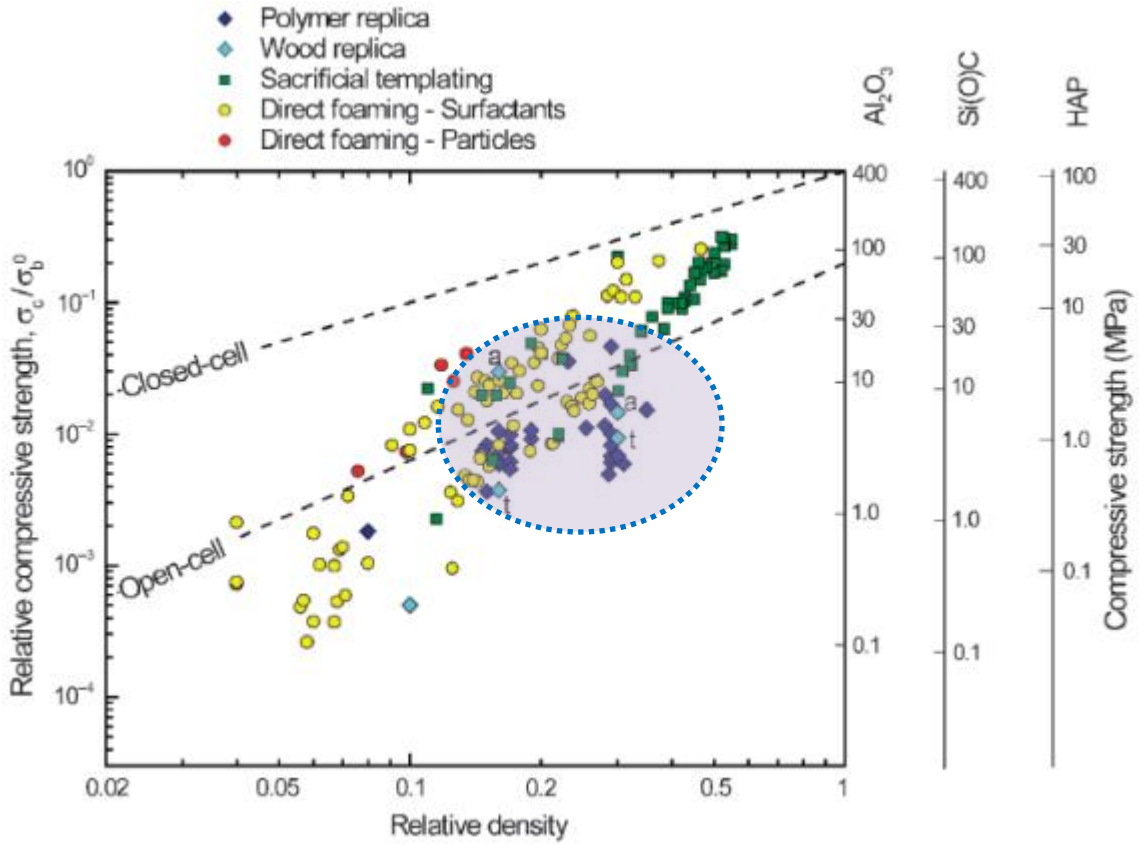
Why Si-SiC foams made via polymer replica?

Porosity vs pore size



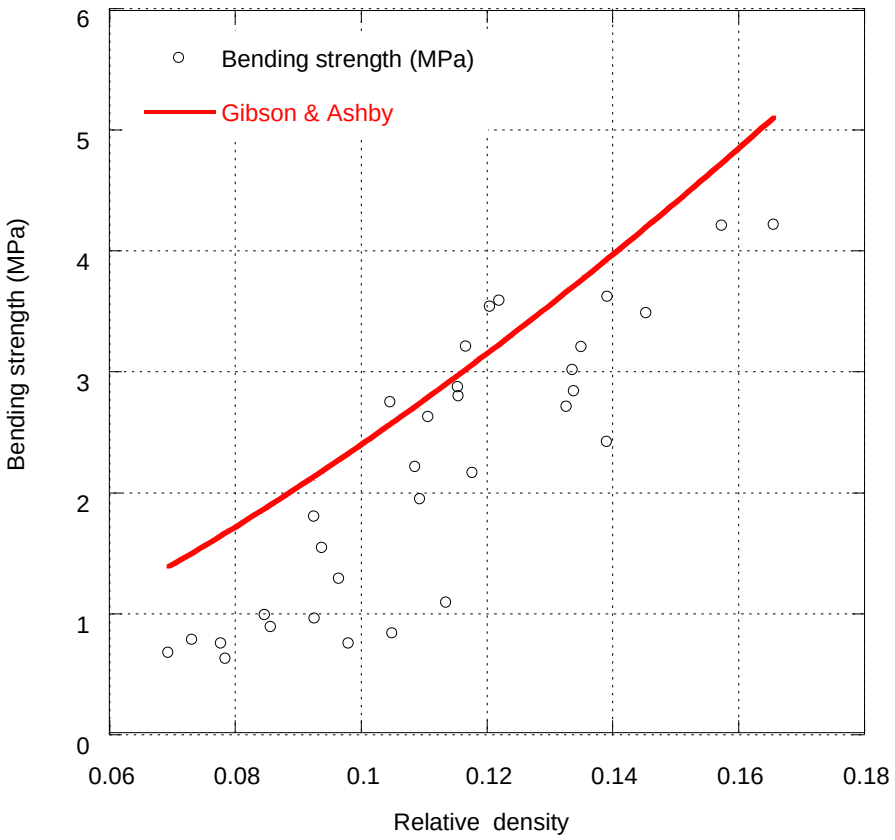
R. Studart, U. Gonzenbach, E. Tervoort, L.J. Gauckler "Processing Routes to Macroporous Ceramics: A Review" J. Am. Ceram. Soc., 89 [6] 1771–1789 (2006)

Mechanical properties (compression)



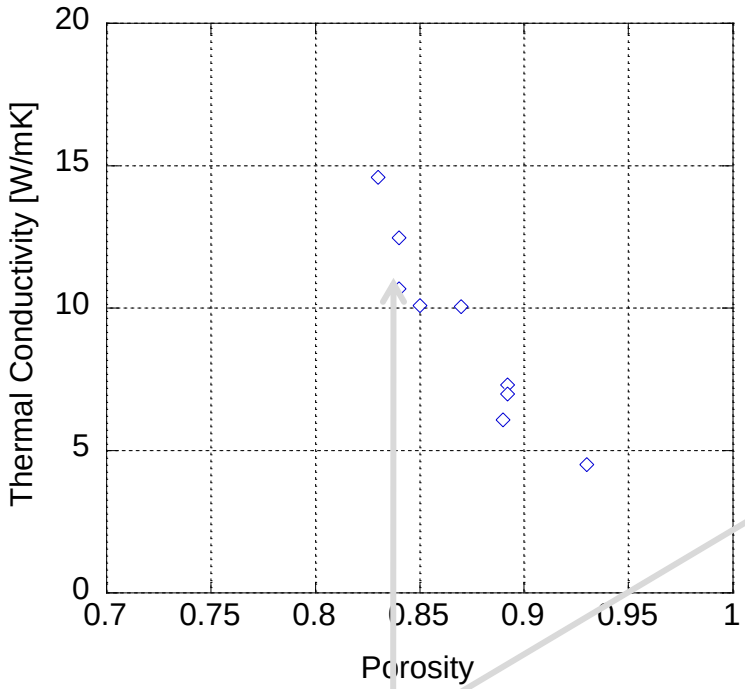
R. Studart, U. Gonzenbach, E. Tervoort, L.J. Gauckler "Processing Routes to Macroporous Ceramics: A Review" J. Am. Ceram. Soc., 89 [6] 1771–1789 (2006)

Mechanical properties (bending)

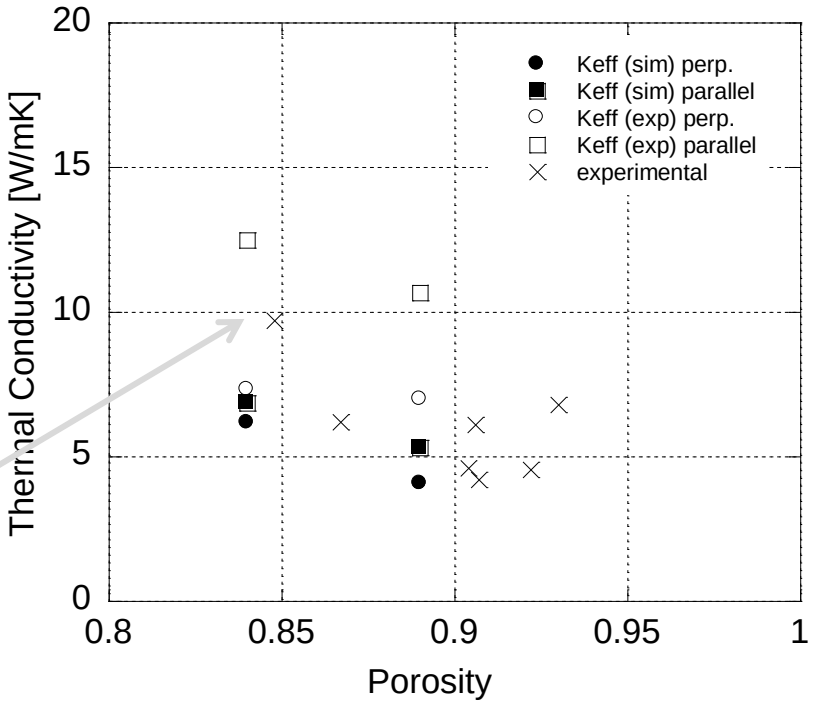


A. Ortona, S. Pusterla, P. Fino, F. R. A. Mach, A. Delgado, S. Biamino, “Aging of reticulated Si-SiC foams in porous burners” Advances in Applied Ceramics, 2010,Vol. 109, n°4, pp 246-251

Heat Conduction through reticulated foams



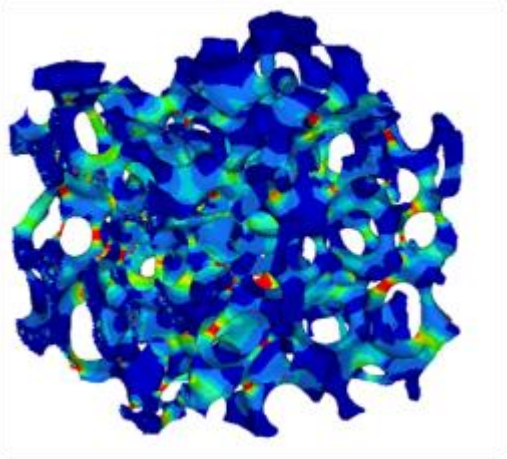
standard 10 ppi foam



Anisotropy of thermal conductivity

A. Ortona, S. Pusterla, S. Valton" Reticulated SiC foam X-ray CT, meshing, and simulation" Advances in Bioceramics and Porous Ceramics III, Ceramic Engineering and Science Proceedings, Roger Narayan and Paolo Colombo, Editors, Wiley, 2011.

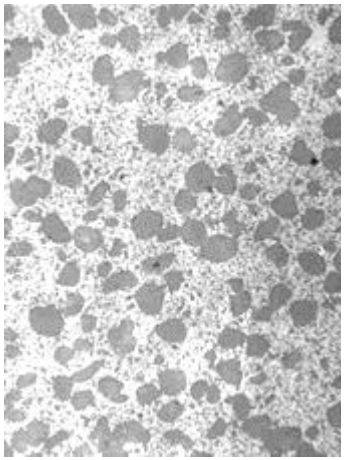
How heat flows through reticulated foams (by conduction)

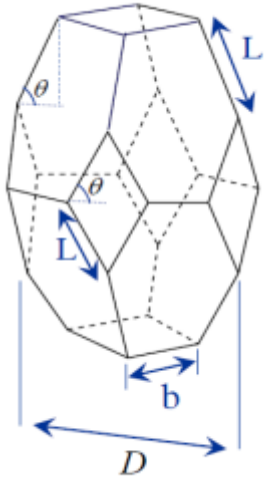


X-ray micro-CT ⇨ Image processing ⇨ Meshing ⇨ Simulations

A. Ortona, S. Pusterla, S. Valton" Reticulated SiC foam X-ray CT, meshing, and simulation" Advances in Bioceramics and Porous Ceramics III, Ceramic Engineering and Science Proceedings, Roger Narayan and Paolo Colombo, Editors, Wiley, 2011.

What affects thermal conductivity?





Material ⇨ Strut * ⇨ Cell

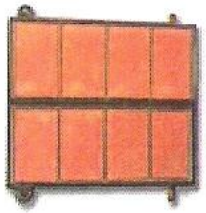
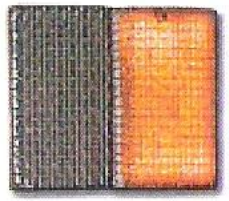
* W.-Y. Jang et al. / International Journal of Solids and Structures 45 (2008) 1845–1875

Si-SiC foams applications

Porous Burners

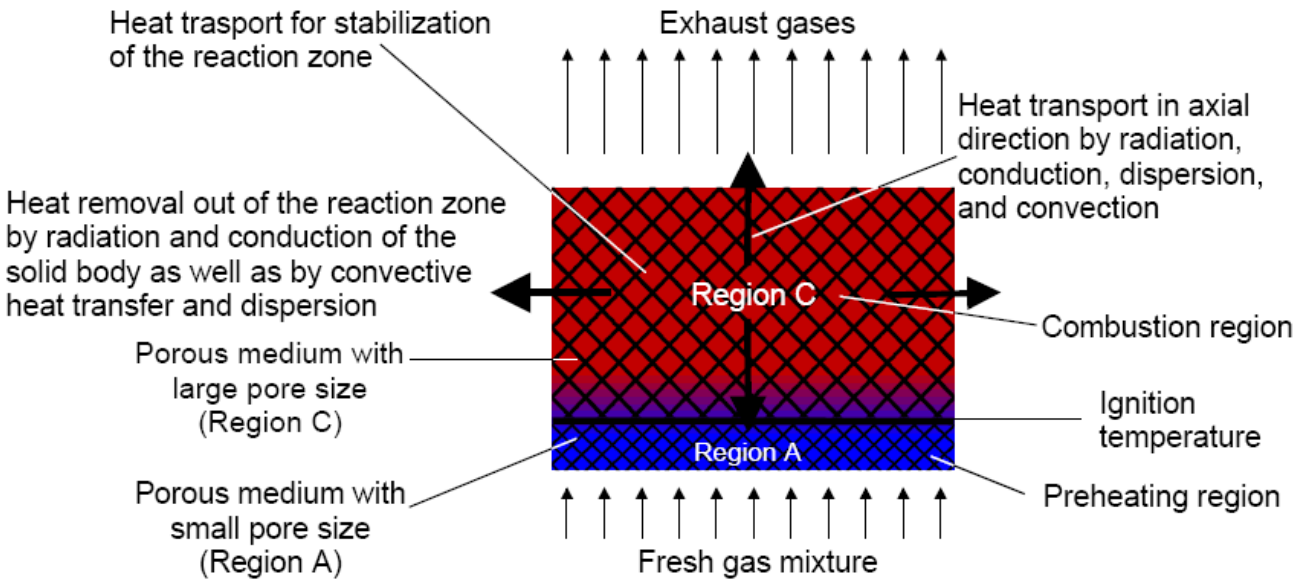
RADIMAX test stand (Source GOGAS)

Porous Burners

					
Typ	**Katalytstrahler**	**Keramikstrahler**	**Metallfaserstrahler** gestrickte Oberfläche	**Metallfaserstrahler** gesinterte Oberfläche	**Porenstrahler**
Art	Langwelliger Strahler	Mittelwelliger Strahler	Mittelwelliger Strahler	Mittelwelliger Strahler	Kurzwelliger Strahler
Wellenlänge	3,3 - 5 µm	2,4 µm	2,2 µm	2,2 µm	1,7 µm
Max. Strahlertemperatur	600 °C	950 °C	1050 °C	1050 °C	1450 °C
Max. thermische Flächenbelastung	30 kW/m²	120 kW/m²	200 kW/m²	250 kW/m²	1000 kW/m²

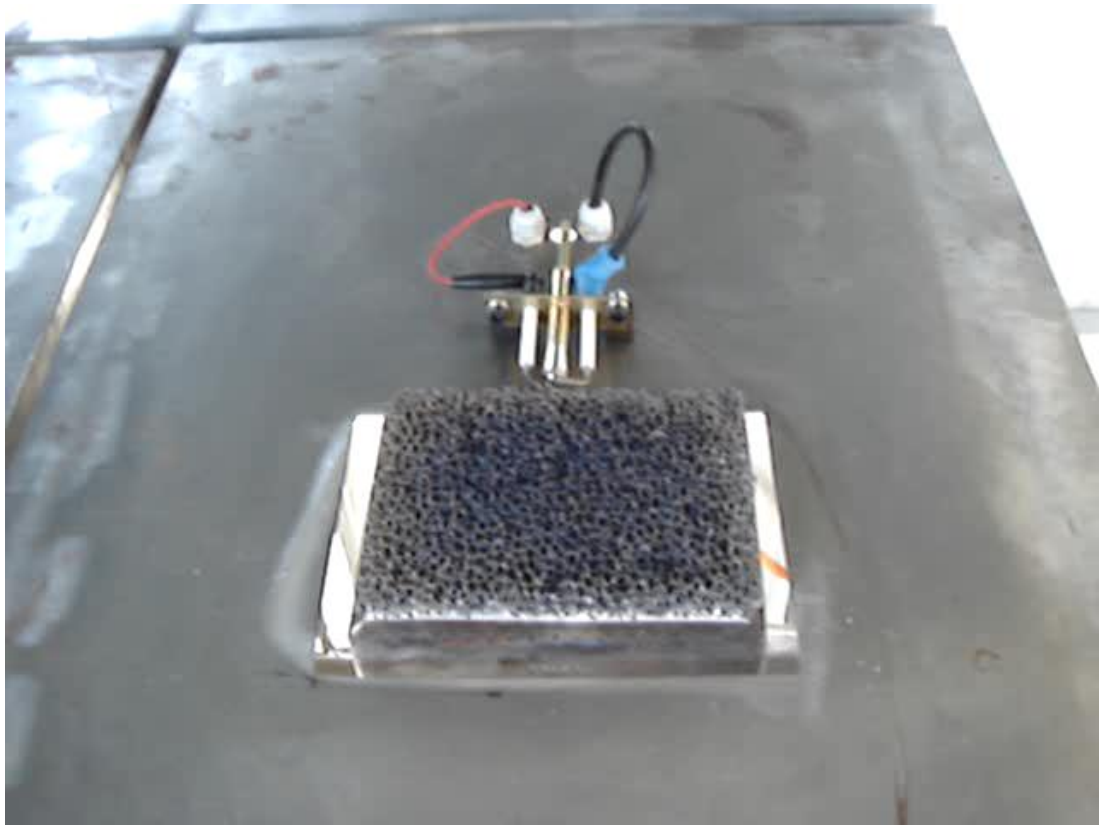
(Source GOGAS web site)

Porous Burners

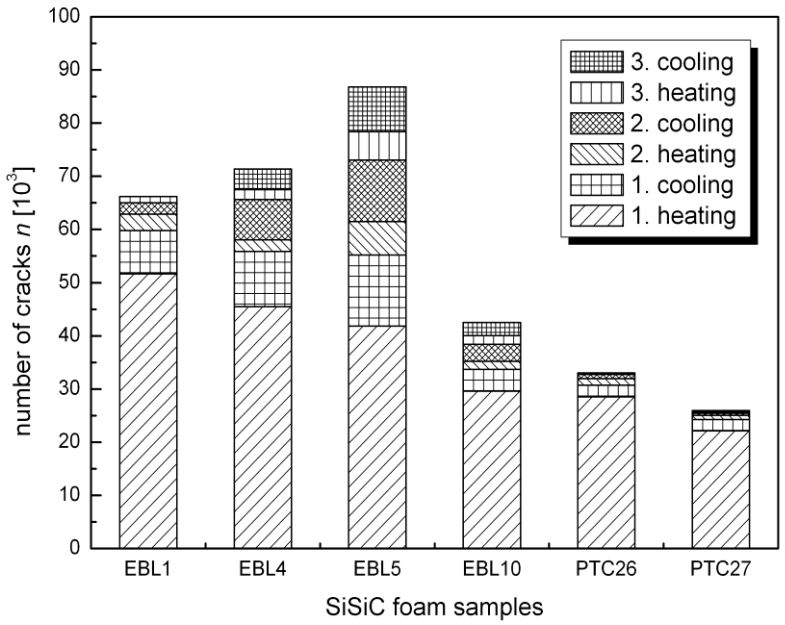


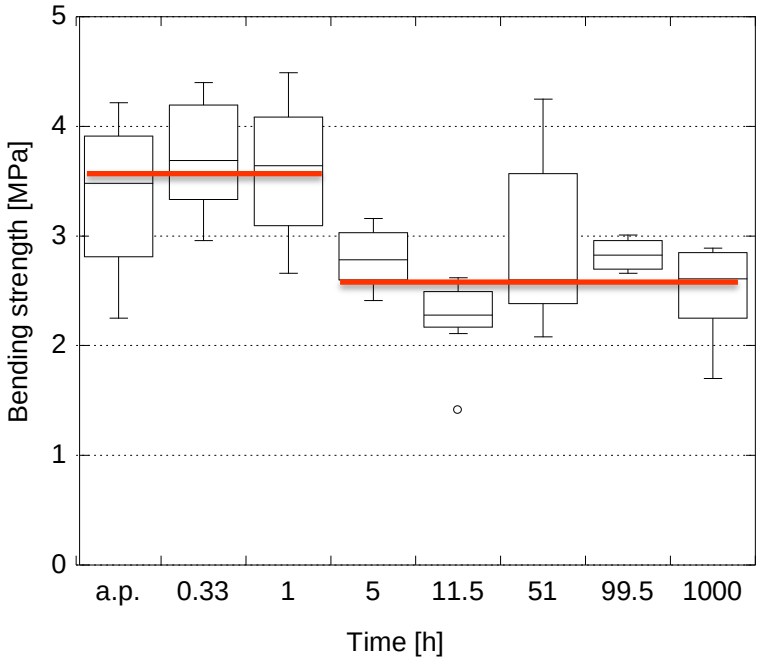
D. Trims, F. Durst, Combustion in porous medium - advances and applications, Combust. Sci. Technol., 121, 153-168 ,1996.

Porous Burners



Porous Burners, aging

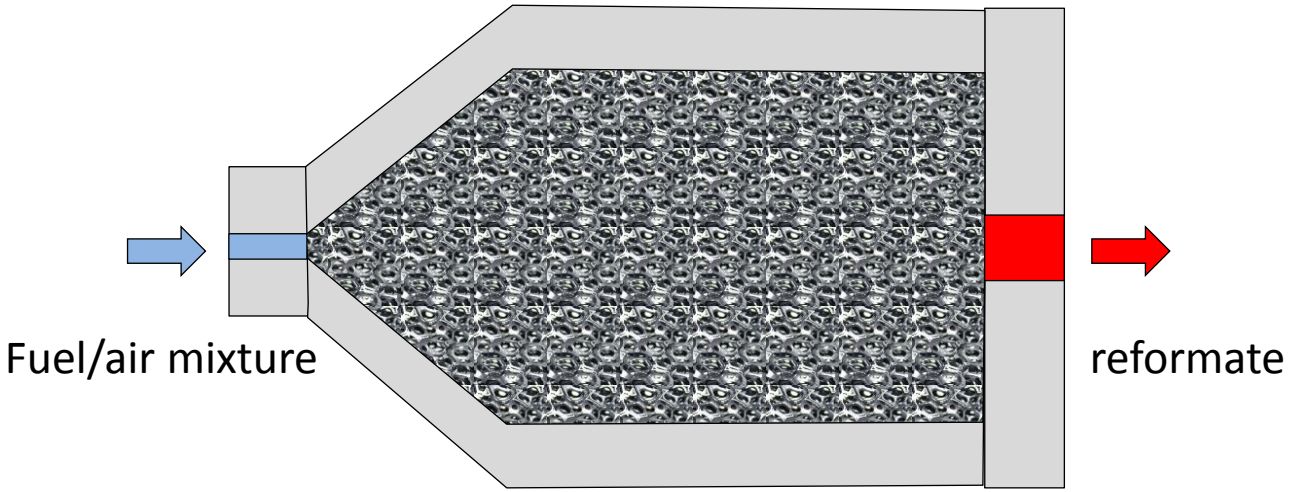




R. A. Mach, F. v. Issendorff, A. Delgado A. Ortona, Experimental investigation of the oxidation behavior of Si-SiC-foams Advances in Bioceramics and Porous Ceramics: Ceramic Engineering and Science Proceedings, Volume 29, Issue 7, 299-311, 2009, WILEY

A. Ortona, S. Pusterla, P. Fino, F. R. A. Mach, A. Delgado, S. Biamino, "Aging of reticulated Si-SiC foams in porous burners" Advances in Applied Ceramics, 2010,Vol. 109, n°4, pp 246-251

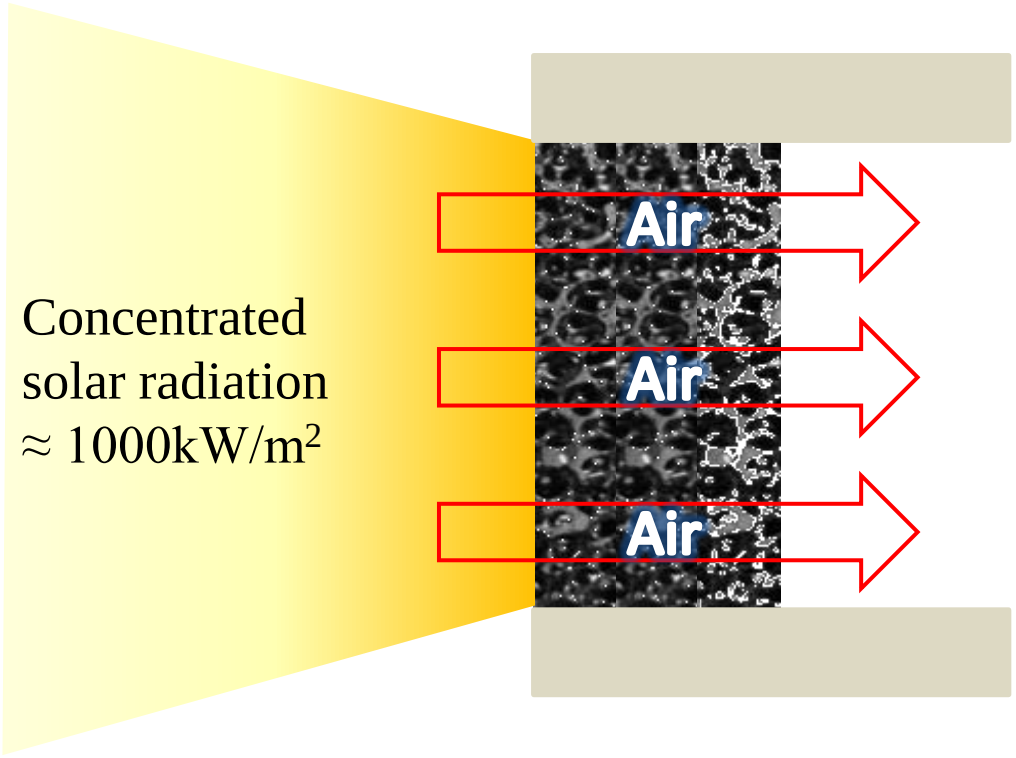
Reformers (TPOX)



Compared with the other reforming technologies the exothermic thermal POX process has no need for external heat sources and additional feeds like water as in steam reforming. The process is catalyst free avoiding catalyst deactivation

Z. Al-Hamamrea, S. Voß, D. Trimis, “Hydrogen production by thermal partial oxidation of hydrocarbon fuels in porous media based reformer”, international journal of hydrogen energy 34 (2009) 827–832
S. Voss, D. Trimis, J. Valldorf, “Development of a Fuel Flexible, Air-regulated, Modular, and Electrically Integrated SOFC-System (FlameSOFC)”, 18th World Hydrogen Energy Conference 2010 - WHEC 2010,Parallel Sessions Book 6: Stationary Applications / Transportation Applications, 2010, Essen

Concentrated solar radiation absorbers



T. Fend, “High porosity materials as volumetric receivers for solar energetic”, Optica Applicata 2010(Vol.40), No.2, pp. 271-284.

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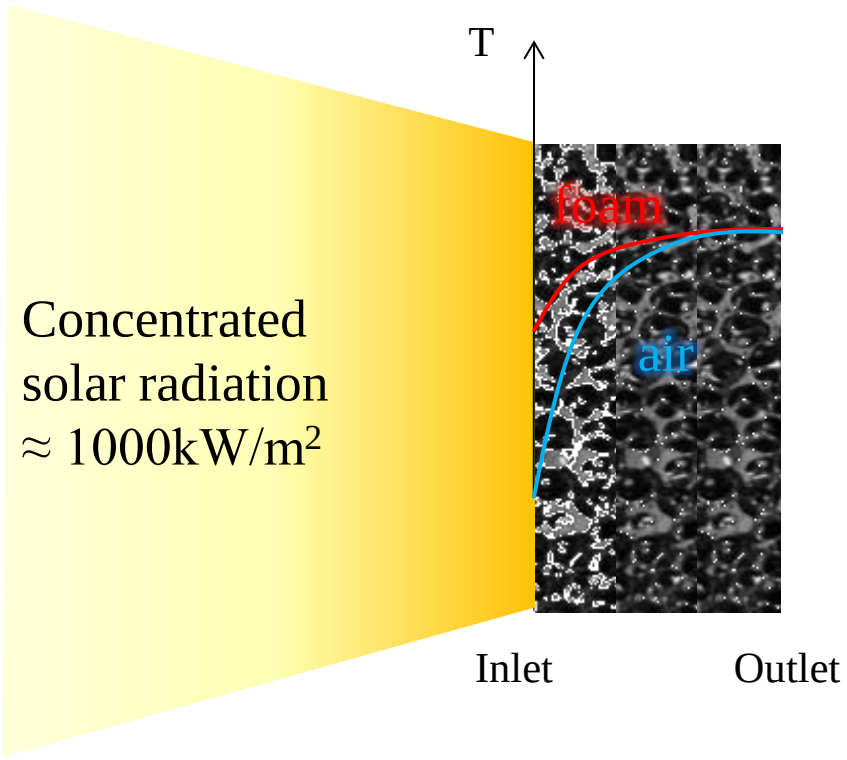

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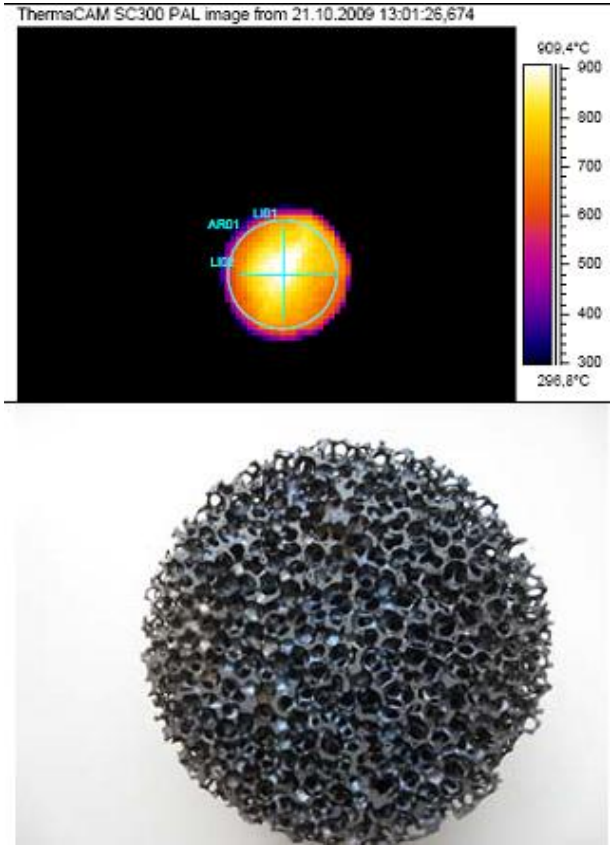
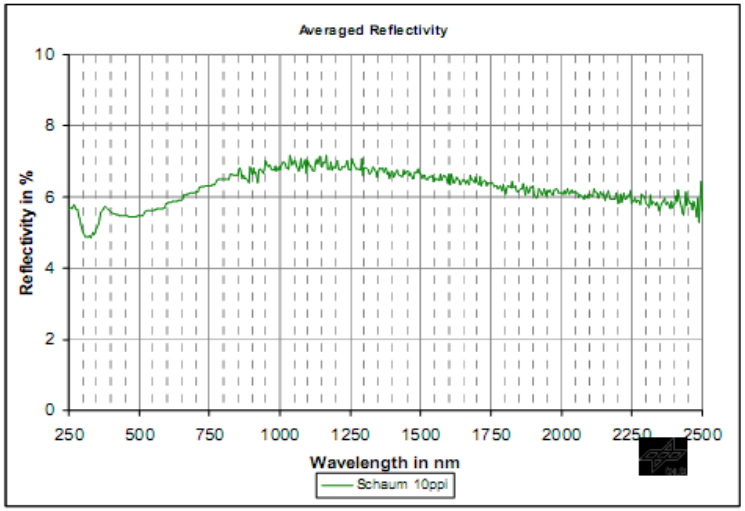
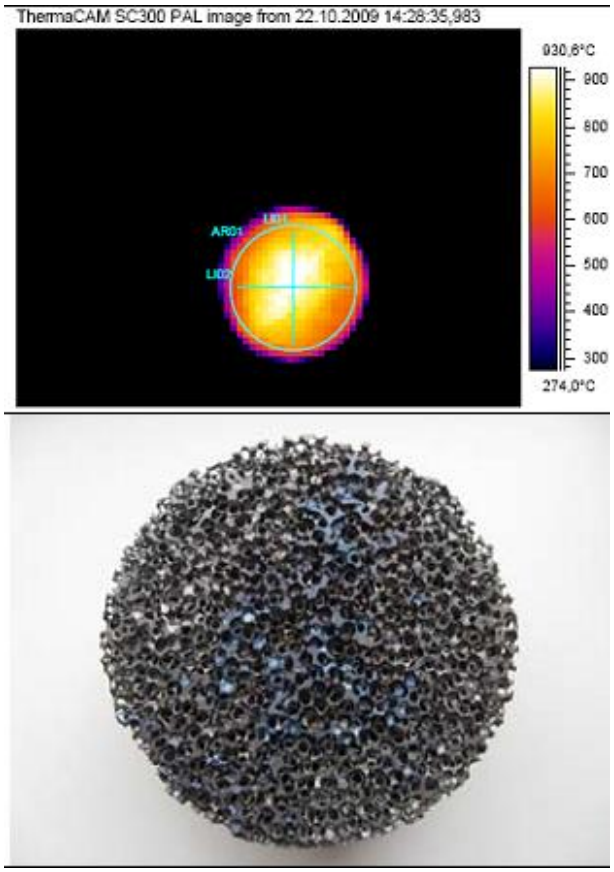


10 PPI foam

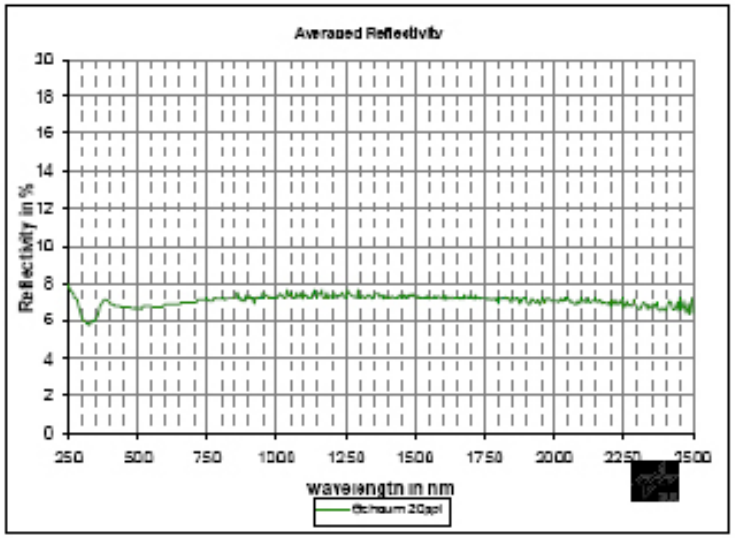


Source DLR (D)

Concentrated solar radiation absorbers

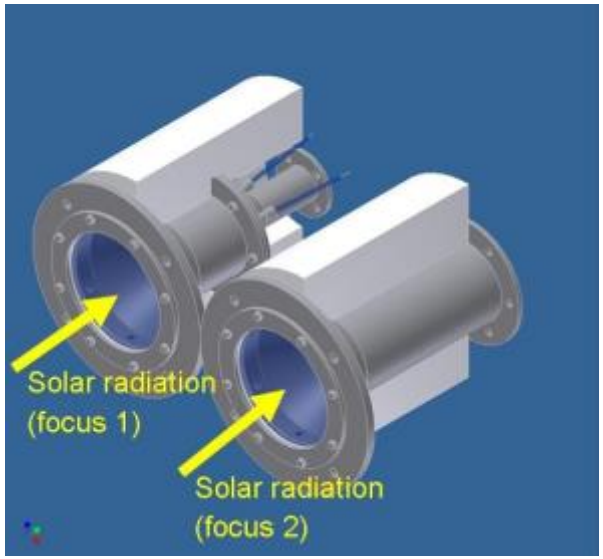


20 PPI foam



Source DLR (D)

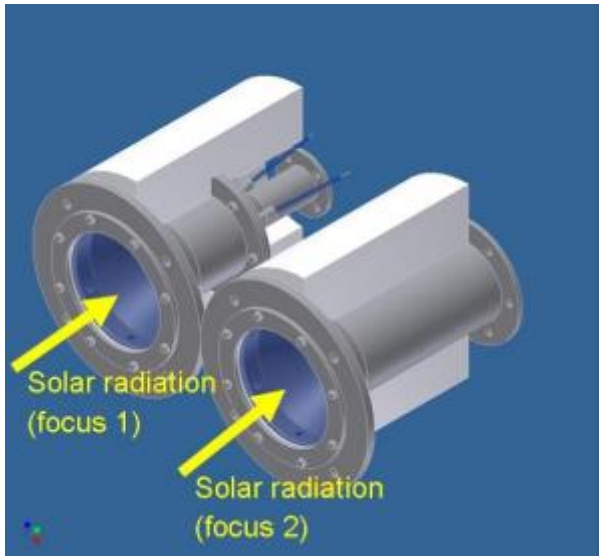
Solar Hydrogen



The key components, necessary for the high temperature part of the process, are a ceramic compact heat exchanger for solar or nuclear SO_3 decomposition, a receiver-reactor for solar H_2SO_4 evaporation and SO_3 decomposition and an oxygen separator.

M. Roeb et al. “HycycleS – A Project on Solar and Nuclear Hydrogen Production by Sulphur-based Thermochemical Cycles” 18th World Hydrogen Energy onference 2010 - WHEC 2010 Parallel Sessions Book 2: Hydrogen Production echnologies Part 1 Proceedings of the WHEC, May 16.-21. 2010, Essen

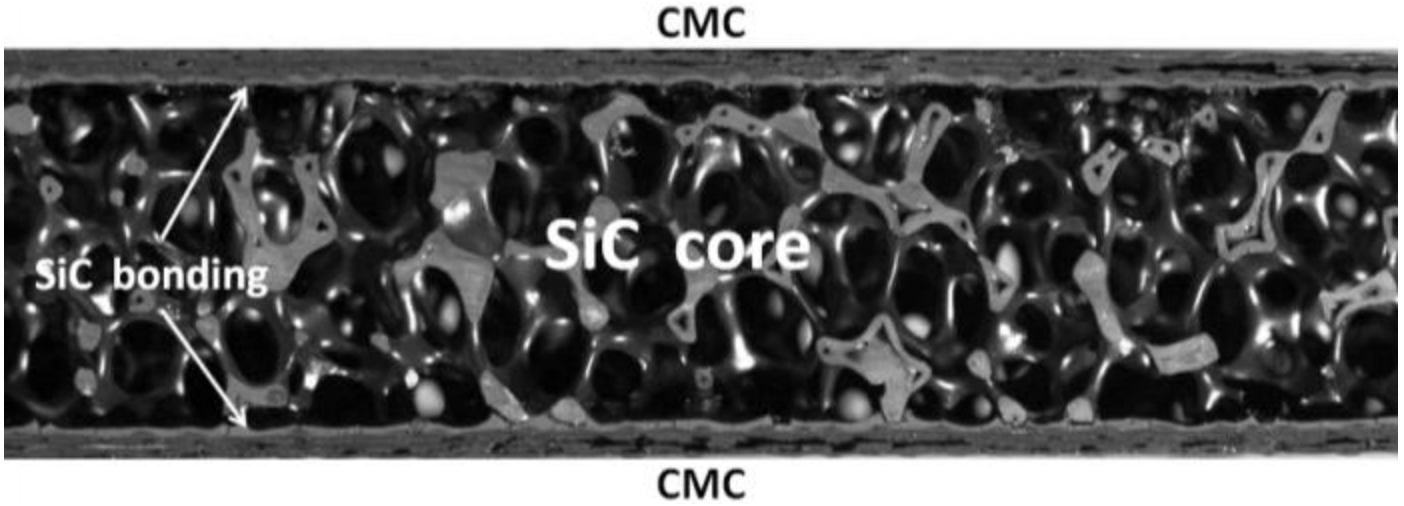
Solar Hydrogen



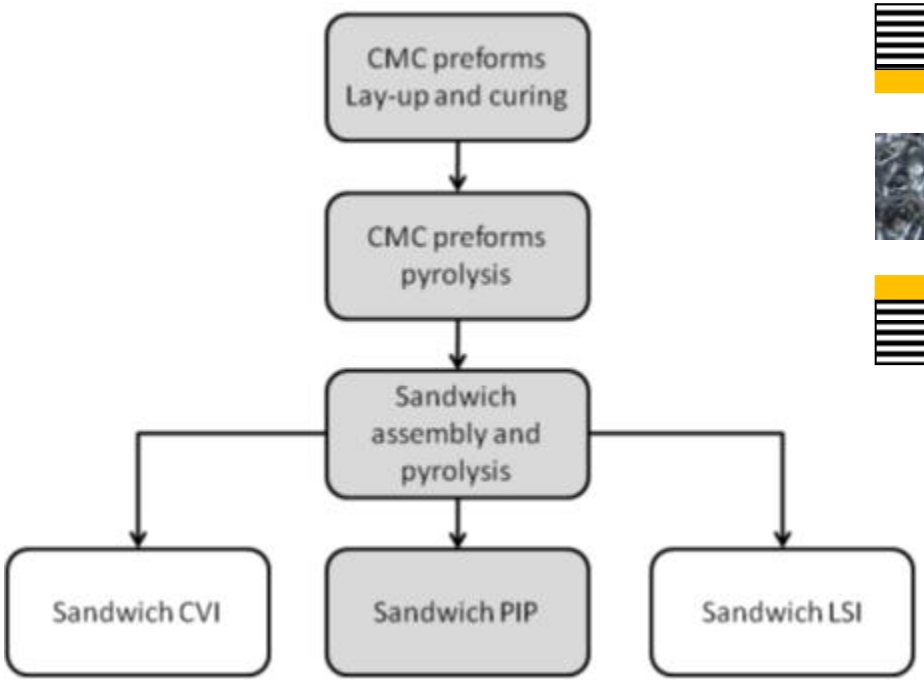
SiC based materials, withstand the conditions and keep their structural integrity over a substantial period of time (1000 hrs).

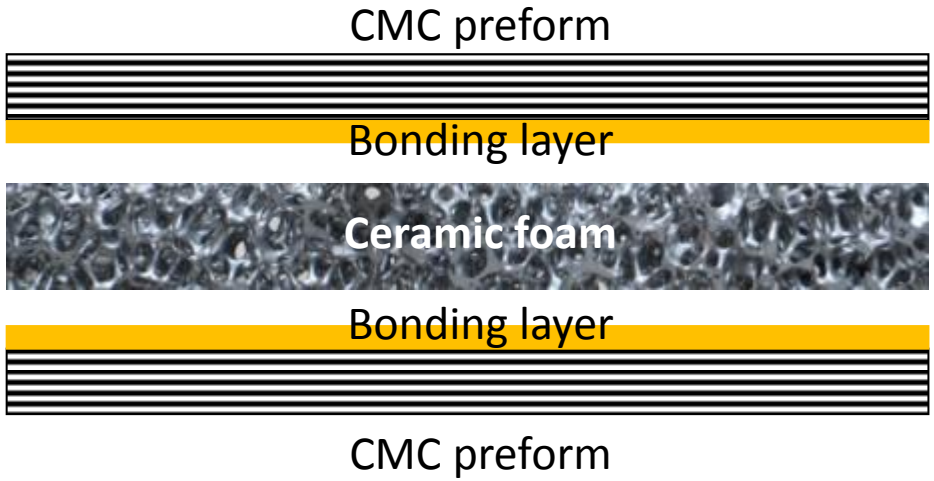
M. Roeb et al. “HycycleS – A Project on Solar and Nuclear Hydrogen Production by Sulphur-based Thermochemical Cycles” 18th World Hydrogen Energy onference 2010 - WHEC 2010 Parallel Sessions Book 2: Hydrogen Production echnologies Part 1 Proceedings of the WHEC, May 16.-21. 2010, Essen

Structural applications



Structural applications





Structural applications

Structural applications

FP7-SPACE PROGRAM 2010

Multifunctional Components for Aggressive Environments in Space Applications (SMARTEES) (Ref. 262749)

Partners:

Austrian Institute of Technology	(A)
Demokritos	(GR)
EADS Innovation Works	(D)
Erbicol	(CH)
INASMET-Tecnalia	(E)
POLITO	(I)
SUPSI	(CH)

Objective:

Development ceramic composites structures, in those space applications where aggressive environments (oxidative) and temperatures are required, such as hot parts of space vehicles for orbital re-entry (RLVs).

SiC foams for high temperature applications

Alberto Ortona
University of Applied Sciences (SUPSI), The iCIMSI Research Institute, Galleria 2, CH 6928, Manno, Switzerland

Sandro Gianella, Daniele Gaia
Erbicol SA. Viale Pereda 22 P.O. Box 321. 6828. Balerna. Switzerland

Avizo