SiC foams for high temperature applications

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Outline

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

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porosity</td>
<td>0%</td>
</tr>
<tr>
<td>Tensile Strength, Ultimate</td>
<td>400 MPa</td>
</tr>
<tr>
<td>Modulus of Elasticity</td>
<td>350 GPa</td>
</tr>
<tr>
<td>Compressive Yield Strength</td>
<td>2000 MPa</td>
</tr>
<tr>
<td>Poissons Ratio</td>
<td>0.24</td>
</tr>
<tr>
<td>CTE, linear at room Temperature</td>
<td>4.30 µm/m-°C</td>
</tr>
<tr>
<td>Specific Heat Capacity at room Temperature</td>
<td>1.10 J/kg K</td>
</tr>
</tbody>
</table>
Why Si-SiC?

<table>
<thead>
<tr>
<th>Material</th>
<th>Density [g/cm³]</th>
<th>Thermal Conductivity [W/mK]</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiSiC</td>
<td>2.90</td>
<td>160</td>
</tr>
<tr>
<td>Yittria</td>
<td>3.96</td>
<td>46</td>
</tr>
<tr>
<td>Nickel</td>
<td>8.9</td>
<td>2.2</td>
</tr>
<tr>
<td>Allumina</td>
<td></td>
<td>9.8</td>
</tr>
</tbody>
</table>
Macroporous reticulated Si-SiC foams
Macroporous reticulated Si-SiC foams

4mm
Si-SiC foams manufacturing

Why Si-SiC foams made via polymer replica?
Porosity vs pore size

Mechanical properties (compression)

Mechanical properties (bending)

Heat Conduction through reticulated foams

How heat flows through reticulated foams (by conduction)

What affects thermal conductivity?

Material → Strut * → Cell

Si-SiC foams applications
Porous Burners

RADIMAX test stand (Source GOGAS)
## Porous Burners

(Source GOGAS web site)

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

(Source GOGAS web site)
Porous Burners
Porous Burners, aging


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.


Concentrated solar radiation absorbers

Concentrated solar radiation
≈ 1000kW/m²

Concentrated solar radiation absorbers

Concentrated solar radiation
\( \approx 1000\text{kW/m}^2 \)

Concentrated solar radiation absorbers

10 PPI foam

Source DLR (D)
Concentrated solar radiation absorbers

20 PPI foam

Source DLR (D)
The key components, necessary for the high temperature part of the process, are a ceramic compact heat exchanger for solar or nuclear SO₃ decomposition, a receiver-reactor for solar H₂SO₄ evaporation and SO₃ decomposition and an oxygen separator.

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

Structural applications

![Diagram of SiC bonding and SiC core within CMC material](image-url)
Structural applications

CMC preform
Bonding layer
Ceramic foam
Bonding layer
CMC preform
Structural applications
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).
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