CeraComp®
Ceramic Matrix
Composites
Why CMCs

• Suitable for use in extreme operating temperature environments (→ 600ºC)
• Lightweight (density ≈ 2.0 g/cm³)
• Chemically resistant
• Thermally insulative
• Tailorable thermal/mechanical properties
• Improved structural integrity and fracture resistance compared to monolithic ceramics
Components of CMCs

- Pre-ceramic polymer
- Fillers
- Reinforcing fibers
Ceramic Matrix Composites - PIP process

Raw Materials → Mold (Apply Heat and Pressure) → “Green State” Part → Machine to “Near Net Shape” → High-Temp Bake → Ceramic Part

Infuse to Densify → High-Temp Bake → Ceramic Part

Densification/Curing Cycle

Fully Dense? → Yes → Machine to Final Dimensions

No → No
Lancer CMC Materials

- **CeraComp® 1100**
  - SiOC matrix with continuous carbon fiber
  - Currently being characterized by Lancer

- **CeraComp® 1102**
  - SiOC matrix with chopped carbon fiber
  - Currently being characterized by Lancer

- **CeraComp® 1201**
  - SiOC matrix with continuous ceramic fiber
  - Similar to Blackglas™ (Honeywell)
  - Fully characterized by U.S. Government*

# CMC Typical Properties

<table>
<thead>
<tr>
<th>PROPERTIES</th>
<th>UNITS</th>
<th>CeraComp® 1100</th>
</tr>
</thead>
<tbody>
<tr>
<td>DENSITY</td>
<td>g/cm³</td>
<td>2.00</td>
</tr>
<tr>
<td>MAX SERVICE TEMPERATURE</td>
<td>°C</td>
<td>600</td>
</tr>
<tr>
<td>ULTIMATE TENSILE STRENGTH</td>
<td>MPa</td>
<td>245</td>
</tr>
<tr>
<td>STRAIN AT FAILURE</td>
<td>%</td>
<td>0.34</td>
</tr>
<tr>
<td>ELASTIC MODULUS</td>
<td>GPa</td>
<td>79.8</td>
</tr>
<tr>
<td>POISSON’S RATIO</td>
<td></td>
<td>0.51</td>
</tr>
<tr>
<td>FLEX STRENGTH (4 PT BEND)</td>
<td>MPa</td>
<td>267</td>
</tr>
<tr>
<td>FLEX STRENGTH (3 PT FLEXURE)</td>
<td>MPa</td>
<td>208.5</td>
</tr>
<tr>
<td>IZOD IMPACT STRENGTH</td>
<td>kJ/m²</td>
<td>213,000</td>
</tr>
<tr>
<td>THERMAL CONDUCTIVITY - RADIAL</td>
<td>W/mK</td>
<td>2.7</td>
</tr>
<tr>
<td>THERMAL CONDUCTIVITY - AXIAL</td>
<td>W/mK</td>
<td>8.1</td>
</tr>
</tbody>
</table>

*Note: Properties reflect typical properties. Actual properties will be dependent upon processing techniques, sample preparation, and test methods.*
## Coefficient of Thermal Expansion

<table>
<thead>
<tr>
<th>CeraComp® 1100</th>
<th>CTE (RT to 100°C)</th>
<th>CTE (RT to 200°C)</th>
<th>CTE (RT to 300°C)</th>
<th>CTE (RT to 400°C)</th>
<th>Ave</th>
</tr>
</thead>
<tbody>
<tr>
<td>OD</td>
<td>0.20</td>
<td>0.30</td>
<td>0.50</td>
<td>0.70</td>
<td>0.43</td>
</tr>
<tr>
<td>ID</td>
<td>-1.17</td>
<td>-0.97</td>
<td>-0.80</td>
<td>-0.57</td>
<td>-0.88</td>
</tr>
<tr>
<td>Length</td>
<td>0.63</td>
<td>0.47</td>
<td>0.60</td>
<td>0.77</td>
<td>0.62</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CeraComp® 1102</th>
<th>CTE (RT to 100°C)</th>
<th>CTE (RT to 200°C)</th>
<th>CTE (RT to 300°C)</th>
<th>CTE (RT to 400°C)</th>
<th>Ave</th>
</tr>
</thead>
<tbody>
<tr>
<td>OD</td>
<td>0.50</td>
<td>0.73</td>
<td>0.90</td>
<td>1.07</td>
<td>0.80</td>
</tr>
<tr>
<td>ID</td>
<td>-0.63</td>
<td>-0.43</td>
<td>-0.20</td>
<td>-0.07</td>
<td>-0.33</td>
</tr>
<tr>
<td>Length</td>
<td>2.93</td>
<td>2.90</td>
<td>3.07</td>
<td>3.47</td>
<td>3.09</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CeraComp® 1201</th>
<th>CTE (RT to 100°C)</th>
<th>CTE (RT to 200°C)</th>
<th>CTE (RT to 300°C)</th>
<th>CTE (RT to 400°C)</th>
<th>Ave</th>
</tr>
</thead>
<tbody>
<tr>
<td>OD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ID</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

All dimensions μm/m-°C  
Test Specimen: Ø4.13in [105mm] O.D. x Ø2.12in [54mm] I.D. x 2.00in [51mm] Length
Impact Test (Gardner)

Test Details:
- Modified ASTM D5420 Method
- Gardner Impact Test

<table>
<thead>
<tr>
<th>Material</th>
<th>Mean Failure Energy*</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicon Carbide</td>
<td>18.75 kg·cm</td>
<td>Shattered</td>
</tr>
<tr>
<td>CeraComp® 1102</td>
<td>28.75 kg·cm</td>
<td>Very Fine Crack</td>
</tr>
</tbody>
</table>

*Mean Failure Energy required to crack or break the sample. A higher mean failure energy is better.
Thermal Shock Test

Test Details:
- ASTM 1525
- Determination of thermal shock resistance by water quench
- Flexural strength measured post quench

Results:

<table>
<thead>
<tr>
<th>Exposure Temperature °F [°C]</th>
<th>CeraComp® 1102 Average Flexural Strength psi [MPa]</th>
<th>Silicon Carbide Average Flexural Strength psi [MPa]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient</td>
<td>22,014 [151.8]</td>
<td>49,587 [341.9]</td>
</tr>
<tr>
<td>572°F [300°C]</td>
<td>46%</td>
<td>100%</td>
</tr>
<tr>
<td>752°F [400°C]</td>
<td>62%</td>
<td>100%</td>
</tr>
<tr>
<td>932°F [500°C]</td>
<td>46%</td>
<td>Samples shattered</td>
</tr>
<tr>
<td>1112°F [600°C]</td>
<td>36%</td>
<td>Samples shattered</td>
</tr>
</tbody>
</table>
Water Lubricated Bearing Tests

- Horizontal bearing tester
- Shaft speed = 1800 rpm
- Contact stress = 250 psi
- Stellite 1 coated stainless steel 304 shafts
- Water flow rate = 1.66 gpm
- Test interval = 1 hour

**Wear Scar Depth on Stellite 1 Coating**

- CeraComp 1100
- CeraComp 1102
- SiC
- SiC30

**Depth (mm)**

- Imperceptible polishing/run-in wear
- Excessive wear to a depth of 0.85 mm
Chemical Compatibility Guide

CeraComp®1100a

Rating Values
1. No detectable change in thickness, and no detectable weight loss, or minor weight gain
2. No detectable change in thickness, but minor weight loss
3. Structurally intact but detectable change in thickness, or substantial weight loss
4. Significant losses in weight or structural integrity

Solvents
Strong Alkalis
Strong Acids
Oxidizing Acid
Weak Acides
Amines
Simple Salts

2800 Milford Square Pike • Quakertown, PA 18951
Tel: 610-973-2800 • www.lancer-systems.com
Thermal Insulation Test

- Multiple exposure & single-extended exposure to jet engine temperature (1600°F/871°C)

Test specimen: 12” x12”, two-layer plate.
  - Layer #1 – 0.25” thick CMC, carbon fiber.
  - Layer #2 – 0.25” thick CMC, glass fiber.

- 1/10 scale F414 engine, Univ. of Mississippi’s National Center for Physical Acoustics

- Four exposures within 73 minutes.
- No thermal hysteresis experienced.

- 1600°F (871°C) at surface of test specimen, 7.5 minutes.
- 150°F (66°C) max temp detected at underside of test specimen.
Thermal Insulation Test, con’t

- Two-minute exposure to oxygen-acetylene torch

![Graph showing temperature change over time](image)

Test specimen: 4” x 4”, three-layer plate.
- Layer #1 — 0.25” thick CMC, carbon fiber.
- Layer #2 — 0.25” thick CMC, glass fiber.
- Layer #3 — 0.25” thick CMC, glass fiber.

- 2200°F (1204°C) at surface of test specimen, two minutes.
- 157°F (69°C) max temp detected at underside of test specimen.
Manufacturing

- Max. Size of Shapes Produced to Date:
  - Plate:
    - 300 mm x 300 mm (12 in. x 12 in.)
    - 25 mm thick (1 in.)
  - Tube:
    - 300 mm (12 inch) O.D.
    - 19 mm (0.75 inch) wall thickness
    - 560 mm (22 inch) length
  - Rod:
    - 150 mm (6 inch) O.D.
    - 125 mm (5 inch) Length

- Tolerances
  - When required, manufacturing has been able to hold 0.015mm [0.0005 in] on critical dimensions

- Surface Finish
  - 0.8μm [32μin] Ra standard surface finish is typical
    - We have achieved surface finish of 0.2μm [8μin] Ra standard
Why Choose Lancer Systems?

Lancer has invested significant resources over four years to develop world-class CMC materials and processes. Our materials are mature and have been successfully demonstrated in a wide variety of applications.

At Lancer, our team is your team. Our people work directly with you as your collaborative partner to design, develop and manufacture lightweight, cost effective, and innovative material solutions.