Aerogels
The Future of Thermal Insulation for Space Applications

making space a global endeavour
Contents

Company Profile
Aerogels
Future Perspectives
Contacts
# Company Profile

## Founded in 2004

- Staff with more than 15 years of experience in mechanics and electronics
- Over 10 years of research and development experience in the aerospace industry

## Role

- Offering high value services to R&D institutions, systems integrators, and SMEs
- Fostering edge products development and technology transfer

## Mission Statement

- Providing mechanical and electronics engineering state of the art expertise
- Offering turn-key subsystems, supplying the whole value-chain from requirements definition, CAD services, and modelling up to manufacturing and AIT
# Company Profile

## Offices
- Coimbra, Portugal
- Berlin, Germany
- Noordwijk, The Netherlands

## Legal Status
- Private Capital
- Small and Medium Entreprise (SME)
- Shareholders of CEIIA

## Organigram

```
Active Space Technologies S.A. Portugal    Active Space Technologies GmbH Germany    Active Space Technologies vof The Netherlands    IMPL Lda Portugal
  Bruno Carvalho, CEO                    Riccardo Nadalini, DG                     Bruno Carvalho, Manager                      João Baptista, Manager
                                          Structural CAD                           Thermal Technology Transfer                  Technology Transfer Commercial
                                          Embedded Systems Digital Control         Project Management                         
```

```
Precision Mechanics AIT
```
<table>
<thead>
<tr>
<th><strong>Services</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Conceptual Design</strong></td>
</tr>
<tr>
<td>3D CAD Design</td>
</tr>
<tr>
<td>2D Drawings, built-to-print</td>
</tr>
<tr>
<td><strong>Engineering</strong></td>
</tr>
<tr>
<td>Thermal Analysis</td>
</tr>
<tr>
<td>Structural Analysis</td>
</tr>
<tr>
<td>CFD</td>
</tr>
<tr>
<td>Electronics</td>
</tr>
<tr>
<td>Control</td>
</tr>
<tr>
<td>Materials R&amp;D</td>
</tr>
<tr>
<td><strong>Manufacturing</strong></td>
</tr>
<tr>
<td>CAM Design</td>
</tr>
<tr>
<td>Precision CNC</td>
</tr>
<tr>
<td><strong>Technology Transfer</strong></td>
</tr>
<tr>
<td><strong>Project Management</strong></td>
</tr>
</tbody>
</table>
Materials

Market opportunities
- Proof of Concept apps, innovative materials
- Benchmarking competitors and opportunities
- Promotion Space Agencies, End-Users

Development
- Requirements definition for apps and missions
- Test Plans relevant assessments, test sequence
- Design and Analysis of Experiments

Qualification
- Space Compatibility assessments
- Integration integration solutions in final apps

Aerogels
- Monolithic Flexible Aerogels
- Tailored Properties

Space Insulation Systems
- Design aerogel-based insulation
- Manufacturing of aerogel insulation
- Performance evaluation space environments

Proof of Concept  Development  Qualification  Marketing
Aerogels
Aerogels

**Structure and performance**

- Highly porous structure (~98%)
- Nanoporous (2-100nm)
- Lightest material known (1-100 g/L)
- Superinsulation (4-25mW/mK)
- Tailorability for broad range applications
- Market in large expansion
Distinguish Advantages for Space Thermal Insulation

Aerogel vs. Multi-Layer Insulation (MLI):
MLI easily falls under access restrictions in Europe
MLI has a cumbersome manufacture
Aerogel can provide thermal insulation as a single material
Aerogel is industrially producible (greater quality assurance)

Thermal insulation for planetary landers and rovers:
MLI is not efficient in environments where the atmosphere plays a role

Insulation of cryogenic propulsion systems:
Conformational flexible aerogel blankets can provide better insulation performance than traditional foams
Benchmarking

Aerogel Solutions

R&D production level:
- Rigid products
- Low maturity level
- Improved mechanical properties require expensive raw-materials

Commercial composite solutions:
- Offer high technological maturity, superinsulation, flexible insulation
- Cause extensive, dust contamination, are heavier than non-composite aerogels

Aerogels Products

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspen Aerogels</td>
<td>Cryogel</td>
<td>0.0135</td>
<td>0.13</td>
<td>-200</td>
<td>40</td>
<td>Foam-like</td>
</tr>
<tr>
<td></td>
<td>Spaceloft</td>
<td>0.0125 – 0.0135</td>
<td>0.17</td>
<td>-200</td>
<td>200</td>
<td>Hydrophobic</td>
</tr>
<tr>
<td></td>
<td>Pyrogel</td>
<td>0.0145 – 0.0155</td>
<td>0.12 – 0.17</td>
<td>-200</td>
<td>650</td>
<td>Tensile strenght 88kPa</td>
</tr>
<tr>
<td>Separex</td>
<td></td>
<td>0.005 – 0.02</td>
<td>0.1</td>
<td>-</td>
<td>-</td>
<td>PU (monolith)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.0015 – 0.0086</td>
<td>0.209</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.0175 – 0.012</td>
<td>0.26</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>MarkeTech International Inc</td>
<td></td>
<td>0.004 (vac.)</td>
<td>0.1</td>
<td>-</td>
<td>-</td>
<td>Silica (monolith)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.016 (air) (0.01 – 0.3)</td>
<td></td>
<td>-</td>
<td>-</td>
<td>Tensile strenght 18kPa</td>
</tr>
<tr>
<td>Airglass</td>
<td>Airglass</td>
<td>0.021 (20°C) 0.02 (300°C)</td>
<td>0.05 – 0.2</td>
<td>-</td>
<td>-</td>
<td>Silica (monolith)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-</td>
<td>-</td>
<td>60 x 60 x 2 cm³</td>
</tr>
<tr>
<td>Cabot Corporation</td>
<td>translucent IR opac. beds</td>
<td>0.018</td>
<td>0.090 – 0.100</td>
<td>-</td>
<td>-</td>
<td>Silica (beads / particles)</td>
</tr>
<tr>
<td></td>
<td>Fine particle Aerogel beds</td>
<td></td>
<td>0.040 – 0.100</td>
<td>-</td>
<td>-</td>
<td>Hydrophobic</td>
</tr>
<tr>
<td>NanoPore</td>
<td>HP-150</td>
<td>0.0034 – 0.020</td>
<td>0.015 – 0.016</td>
<td>-273</td>
<td>150</td>
<td>VIP</td>
</tr>
<tr>
<td></td>
<td>MT-170</td>
<td>0.0038 – 0.021</td>
<td>0.0166 – 0.017</td>
<td>-273</td>
<td>600</td>
<td></td>
</tr>
</tbody>
</table>
Aerogels Synthesis at Active Space Technologies

Sol-Gel Technology Laboratory protocol: Chemical Engineering Department, University of Coimbra (FCTUC)

Synthesis:
Precursors – silica derivatives
Reaction – two-step catalysed process

Drying:
Ambient Pressure Drying – Xerogels
Supercritical Fluids Drying - Aerogels

Key properties:
Very low density (Aerogels: 50-60 g/L, Xerogels: 70-80g/L)
Low particulate contamination
Flexibility (easy to handle and integrate) (even at -180°C)
Low cost raw-materials

Liquid nitrogen (-180°C)
Silica-based aerogels properties

Nanostructure:
- Skeleton density: 1000-1200 g/L
- Porosity: 93-97%
- Specific Surface Area: 500-900 m²/g
- Mean pore size: 1.5-4.5 nm

Macroscopic:
- Bulk Density: Aerogels – 50-60 g/L; Xerogels – 70-80 g/L
- Hydrophobic: 140° static water contact angle
- Particulate contamination: Very low

Thermal:
- Aerogels oxidation (12% weight loss): 400-500°C
- No mass loss observed at [500-1000]°C
- Specific heat capacity: 1.9-2.3 J/(g.°C) (at 40°C)
- No glass transition observed [tested down to -180°C]
- Coefficient of linear thermal expansion: 1.4-1.5 (K⁻¹)

Mechanical:
- Elastic modulus: 5-30 kPa
- Yield on compression: 7.0-7.0 kPa at 30-35%
- Flexible at low temperatures – Modulus: 60kPa@-170°C, 25kPa@0°C
Aerogels – Thermal Insulation Systems at Active Space Technologies

Aerogel Panels – Development, Manufacture, and Integration

Design and Manufacturing of Aerogel Insulation Panels:
- Easy handling, self-sustainability, non-brittle
- Cleanliness control
- Integrity at environmental changes (P, T)
- Radiation control

Integration and Qualification:
- Easy integration procedures on spacecraft hardware
- Space compatibility assessments
- Qualification testing process
Future Perspectives

Further developments on Aerogels at Active Space Technologies

Tailorability of Aerogels Properties:
New capabilities on manufacturing and applications of nanostructured materials (Network – FP7 MANANO)
Controlled synthesis allows tailorability of aerogel properties to protect different spacecraft devices (thermal and structurally)

Exploitation of On-Earth Aerogels Applications:
- Thermal insulation: industrial and buildings
- Pharmacology: controlled drug delivery systems
- Effluents treatments: oils removal, gases capture

European Aerogels Supplying Unit for Space Applications:
Creation of a large-scale aerogels manufacturing unit
Disruptive project to replace imported MLI with European aerogel technology
Creation of an European aerogels supply chain that can extend into other industrial sectors
## Contact us

For further information, please visit our website [www.activespacetech.com](http://www.activespacetech.com)

<table>
<thead>
<tr>
<th>Name</th>
<th>Email</th>
<th>Tel</th>
<th>Fax</th>
<th>Address</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ricardo Patrício</td>
<td><a href="mailto:ricardo.patricio@activespacetech.com">ricardo.patricio@activespacetech.com</a></td>
<td>+351 239 700 333</td>
<td>+351 239 700 301</td>
<td>Rua Pedro Nunes</td>
<td>Coimbra, Portugal</td>
</tr>
<tr>
<td>Riccardo Nadalini</td>
<td><a href="mailto:riccardo.nadalini@activespacetech.com">riccardo.nadalini@activespacetech.com</a></td>
<td>+49 (0) 30 2654 2797</td>
<td>+49 (0) 30 201 632 829</td>
<td>Rudower Chausee 29</td>
<td>Berlin, Germany</td>
</tr>
<tr>
<td>Bruno Ramos de Carvalho</td>
<td><a href="mailto:bruno.carvalho@activespacetech.com">bruno.carvalho@activespacetech.com</a></td>
<td>+351 967 052 725</td>
<td></td>
<td>De Huygensstraat 34</td>
<td>Noordwijk, The Netherlands</td>
</tr>
</tbody>
</table>