Alternative monolithic/composite carbons for adsorption generators

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  ✓ Carbon + lignin binder
  ✓ Carbon + Expanded Natural Graphite
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Need for improvement of thermal properties of carbon

↓ Contact resistance

↑ Thermal conductivity
Carbon + lignin binder mixture
- 15% lignin binder
- 85% carbon (grains, powder or mixture)
- Boiling water (50% weight of carbon mixture)

Compression

Firing, 500 °C and inert atmosphere
Carbon + lignin binder
Carbon + Expanded Natural Graphite

Carbon + ENG mixture:
- 25% ENG
- 75% Carbon (grains, powder or mixture)
- Water (100% weight of carbon)

Compression
Thermal properties measurement techniques

- Anter machine
  - Bulk thermal conductivity

- HyperFlash machine
  - Bulk thermal conductivity

- Large Temperature Jump (LTJ)
  - Bulk thermal conductivity
  - Wall contact resistance
Anter machine

2-inch diametre sample

- Heater
- Upper plate • $Tu$
- Sample
- Lower plate • $Tl$
- Reference calorimeter
- Heat sink • $Th$

Heat flux transducer
Measurement of Thermal Diffusivity and Conductivity

Schematic of the LFA 467 HyperFlash®: the light beam heats the lower sample surface and an IR detector measures the temperature increase on the upper sample surface.

Fraunhofer ISE
Large Temperature Jump (LTJ)

Water

Pressure

Cell

Ammonia

Carbon sample (h, K)

Vessel
LTJ – Carbon sample

Carbon
LTJ – Mathematical model

- Adiabatic surface
- Wall contact resistance
- Carbon
- Steel
- Water

Mathematical model for wall contact resistance and adiabatic surface in a LTJ structure.
Thermal conductivity and wall contact resistance experimental results
FLASH Results – Carbon + lignin binder

![Graph showing thermal conductivity vs. temperature for different materials and load conditions.](Image)

- Powder – 85%
- Powder – 85%
- Grains 20x40 – 85%
- Grains 20x40 – 85%
- Mixture - 85%
- Mixture - 85%

(Compression load = 123 kN dotted & 215 kN solid)
FLASH Results – Carbon + ENG

Thermal conductivity (W/mK) vs. Temperature (°C)

- **Green Line**: Powder - 75%
- **Red Line**: Grains 20x40 - 75%
- **Blue Line**: Mixture - 75%

(Compression load = 215kN)
LTJ Results – Carbon + lignin binder

Carbon mixture:
2/3 20x40 grains
+ 1/3 powder

Dc = 806 kg/m³
Kc ≈ 0.3 W/mK
R_{th} = 0 m²K/W
Comparison Anter, Flash & LTJ results

- Lignin + grains ANTER
- Lignin + grains FLASH
- Lignin + powder ANTER
- Lignin + powder FLASH
- Lignin + mixture ANTER
- Lignin + mixture FLASH
- Lignin + mixture LTJ
- ENG + grains FLASH
- ENG + powder FLASH
- ENG + mixture FLASH
Adsorption characteristics

Modified Dubinin-Astakhov equation:

\[ x = x_0 e^{-K(T/T_{sat} - 1)^n} \]

- \( T \) is the refrigerant/adsorbent temperature (K)
- \( T_{sat} \) is the saturation temperature (K)
- \( x \) is the adsorbed refrigerant concentration (kg/kg)
- \( x_0 \) is the maximum (limiting) concentration (kg/kg)
- \( K \) and \( n \) are constants

<table>
<thead>
<tr>
<th></th>
<th>( x_0 )</th>
<th>( k )</th>
<th>( n )</th>
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</thead>
<tbody>
<tr>
<td>Carbon grains 20x40</td>
<td>0.2877</td>
<td>5.343</td>
<td>1.319</td>
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<tr>
<td>Carbon mixture + lignin binder</td>
<td>0.2296</td>
<td>5.211</td>
<td>1.454</td>
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<tr>
<td>Carbon powder + silane binder</td>
<td>0.2050</td>
<td>6.171</td>
<td>1.597</td>
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</table>
Research strategy

Monolithic carbon
- Density
- Specific heat
- Conductivity
- Contact resistance
- Porosity
- Stability

Silane bonded carbon

ENG matrix carbon

- Shell and tube simulation
- Finned tube simulation

Optimised shell and tube design
Optimised finned tube design

Designed choice
Thanks for your attention!

Any questions?