Design Concepts and Materials for Thermal Propagation Prevention

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3M Company

➢ more than a “Tape and Films Company”
➢ 46 Core Technology Platforms
➢ Ceramics, Advanced Materials, Nonwoven Materials etc.
➢ >25 years of battery materials history
➢ >40 years of ceramic fibre, nonwoven & fire protection history
➢ global team working Thermal Propagation Prevention

46 Core Technology Platforms

3M Battery Materials History: Over 25 years of activity

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C. Middendorf & C. Kuesters CII Automotive Electrification
Fire Protection Strategies for all System Levels

- Stable Cell Chemistry & Design
- Save Operation Management & Failure Detection
- Containment & Retarding
- Preventive Fire Protection active or passive
- Hot Gas Exhaust & Toxic Emissions

From Operation Management to holistic Fire Protection
Fire Protection Technologies

- High Temperature Resistant Ceramic Materials
- “Phase Change” or Endothermic Materials
- Intumescent Materials
- Test Results
High Performance Insulation Material

HT Insulation Material

Test Bench

- material test frame
- load cell
- 2 independent heated platens
- laser controlled gap

Next Steps

- explore new materials
- improve insulation performance

<table>
<thead>
<tr>
<th>Gap [mm]</th>
<th>T (10min) [°C]</th>
</tr>
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<tbody>
<tr>
<td>2.0</td>
<td>193</td>
</tr>
<tr>
<td>3.0</td>
<td>145</td>
</tr>
<tr>
<td>4.0</td>
<td>107</td>
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<tr>
<td>5.0</td>
<td>92</td>
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heat primary plate to 700°C, then start timer
Endothermic Fire Protection Solutions

**Product**
- Mat filled with ceramic fiber and endothermic filler or Film Material only

**Features**
- Cooling effect based on Phase-Change. $H_2O$ & $CO_2$ Release
- Activation temp. 90$°$ C – 300$°$ C
- Material thickness 0.5 mm – 10 mm

<table>
<thead>
<tr>
<th>end. material</th>
<th>decomposition temp. [$°$C]</th>
<th>Enthalpy [kJ/kg]</th>
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<tbody>
<tr>
<td>CaSo4 . 2H2O</td>
<td>60 - 130</td>
<td>560</td>
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<tr>
<td>Al(OH)3</td>
<td>180 - 200</td>
<td>1300</td>
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<tr>
<td>new</td>
<td>~100</td>
<td>~1000</td>
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</tbody>
</table>

• “endothermal plateau”
• temperature increase stopped at 100°C for several minutes
Flame Retardant Barrier

Product

- FRB NT Sheet Material
- Inorganic-based, halogen free material
- thicknesses from 0.08 to 0.38 mm

Features

- High flammability resistance
- Dimensionally stable – minimal shrinkage at elevated temperatures < 0.3 %
- High Arc resistance
- Densified for high Dielectric strength > 3 KV
- Low volatile outgassing < 22 ppm

Nextel™ Ceramic Textile

- Flame Propagation Test as per ISO2685, after 15 min exposure there is no flame penetration and no after flame
Intumescent Fire Protection Material, Coatings and Films

Product

• Intumescent Material expands multiple times
• Formation of a stable and insulating Foam
• Matt, Film or Coating
• Heat-activated Spacer or Sealing

Features

• Uniaxial or multi-axial Expansion from 3X to 15X
• Activation Temp.: 150°C - 350°C
• Flexible to firm Material Matts

<table>
<thead>
<tr>
<th>Tech. Properties</th>
<th>I-10</th>
<th>FS-195</th>
<th>E-FIS</th>
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<tbody>
<tr>
<td>caliper (mm)</td>
<td>1.7</td>
<td>5.5-8.1</td>
<td>3</td>
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<tr>
<td>activation temperature (°C)</td>
<td>352</td>
<td>150</td>
<td>200</td>
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<tr>
<td>expansion rate</td>
<td>3X</td>
<td>8X</td>
<td>10X</td>
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</table>
Summary – Prevent Thermal Propagation

Thermal Protection
- Ceramic Non-Woven
- Endothermic Fillers
- Expanding Mats

Flame Barrier
- Thin Inorganic Papers, Woven

Lab Tests
- Exploring Suitable Test Setups

Protect Adjacent Cells/Stacks
- ✓ thermal insulation, “super insulator”
- ✓ absorb thermal energy (cooling)
- ✓ expansion transformed into
  - • volume: → insulation
  - • or force: → spacer, sealing
- ✓ no flame penetration, no/low fumes

✓ proof material & design concepts