3M™ Thermal Management Materials for Automotive Batteries

Electrical Vehicle (EV) and Hybrid Electrical Vehicles (HEV)

July 2015
Keys to Effective Thermal Interface Material Performance

A balanced combination of wet-out and bulk material conductivity ($k$) is key to effective thermal ($R$) solution.

Select bulk material ($k$) based on desired:
- Softness
- Conformability
- Gap Thickness
- Adhesion
- Wet-Out
- Effective Thermal
- Resistance ($R$)

$$Q = \frac{(k/t) \cdot A \cdot dT}{t}$$

$Q$: Heat flow watts

$k$: Thermal conductivity W/m-k

$A$: Area (100% wet-out) $x \%$ wet-out

$t$: Thickness

$dT$: Temperature hot side – Temperature cold side

Helps eliminate air at interface
# Thermal Interface Material Options

<table>
<thead>
<tr>
<th>Technology</th>
<th>Thermal Conductivity vs. Air*</th>
<th>Pros</th>
<th>Cons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grease</td>
<td>20-185X</td>
<td>Thin, low cost&lt;br&gt;Thin=Low Impedance&lt;br&gt;Good wetting</td>
<td>Messy&lt;br&gt;No adhesion so needs mechanical attach</td>
</tr>
<tr>
<td>Liquids</td>
<td>20-125X</td>
<td>Thin=Low Impedance&lt;br&gt;High bond strength&lt;br&gt;Good wetting</td>
<td>Messy&lt;br&gt;Pot life of epoxy&lt;br&gt;Need cure time and fixturing</td>
</tr>
<tr>
<td>Phase Change</td>
<td>20-125X</td>
<td>Good wet-out&lt;br&gt;Less messy than grease&lt;br&gt;Thin=Low Impedance</td>
<td>No adhesion&lt;br&gt;Needs mechanical attach&lt;br&gt;Need initial heat cycle</td>
</tr>
<tr>
<td>Tapes</td>
<td>20-40X</td>
<td>Good wet-out&lt;br&gt;No mechanical fasteners&lt;br&gt;Ease of use</td>
<td>Typically &lt;10-15W applications</td>
</tr>
<tr>
<td>Pads</td>
<td>35-200X</td>
<td>Greater thicknesses&lt;br&gt;Very soft/conformable&lt;br&gt;Gap filling</td>
<td>Light adhesion&lt;br&gt;Needs mechanical fastener&lt;br&gt;Cost</td>
</tr>
<tr>
<td>Solder/Liquid Metal Phase Change Material</td>
<td>500-1000X</td>
<td>Thin thickness&lt;br&gt;High conductivity&lt;br&gt;Gap filling</td>
<td>Difficult to apply&lt;br&gt;Low viscosity when melted&lt;br&gt;CTE&lt;br&gt;Cost</td>
</tr>
<tr>
<td>Heat Spreading Tapes</td>
<td>100-1000X</td>
<td>Value Heat Spreader vs. Graphite&lt;br&gt;Conformable, Easy to die cut, No Splitting from rework</td>
<td>Typically 80-90% performance of Graphite Thermal Tape</td>
</tr>
</tbody>
</table>

*Air Thermal Conductivity = 0.02 W/m-K<br>Green denotes 3M Options
3M™ Thermal Management Materials

Thermally Conductive Interface Tape

Thermally Conductive Interface Pad (Silicone and Acrylic)

Thermally Conductive Grease

Thermally Conductive Adhesives

Thermally Conductive and Heat Spreading Tape

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3M™ Thermally Conductive Interface Materials
Level One Solutions (Tapes, Pads, Greases & Epoxies)

TIM – Tapes
K = 0.2 ~ 1.5 W/m-K

- Good thermal conductivity
- Various thickness (0.05 mm ~ 1 mm)
- Adhesions for various surface
- UL flame resistance option
- Good wet out for lower thermal resistance
- Good dimensional stability
- Good dielectric strength

TIM – Pads
K = 1.0 ~ 4.9 W/m-K

- Good thermal conductivity
- Various thickness (0.5 mm ~ 1 mm)
- Various softness
- UL flame resistance option
- Softness for good wet-out
- Good dimensional stability
- Dielectric strength

TIM – Grease
K = 2.7 ~ > 4.1 W/m-K

3M™ Thermally Conductive Grease TCG-2035/TCG-2031
- High thermal performance, higher viscosity, high value
- K= 4.1 W/m-K
- TCG-2031: screen printable version of TCG-2035

3M™ Thermally Conductive Grease TCG-2036
- Good thermal performance, thin bonding line, lower thermal impedance
- K = 2.7 W/m-k

TIM – Epoxy
K = 0.7 ~ 1.1 W/m-K

- Good bonding strength
- Long term reliability
# 3M™ Thermally Conductive Interface Pads
(Acrylic and Silicone)

<table>
<thead>
<tr>
<th></th>
<th>Acrylic</th>
<th>Thermal Conductivity</th>
<th>Hardness</th>
</tr>
</thead>
<tbody>
<tr>
<td>5570</td>
<td>1.3 W/m-K</td>
<td></td>
<td>Non-Silicone, Acrylic, V-0</td>
</tr>
<tr>
<td>5574</td>
<td>1.5 W/m-K</td>
<td></td>
<td>Non-Silicone, Acrylic, V-0</td>
</tr>
<tr>
<td>5589H/5571</td>
<td>2.0 W/m-K</td>
<td></td>
<td>Non-Silicone, Acrylic, V-0</td>
</tr>
<tr>
<td>5590H/5567H</td>
<td>3.0 W/m-K</td>
<td></td>
<td>Non-Silicone, Acrylic, V-0</td>
</tr>
<tr>
<td>5578H</td>
<td>3.5 W/m-K</td>
<td></td>
<td>Non-Silicone, Acrylic, V-0</td>
</tr>
<tr>
<td>5591(S)</td>
<td>1.0 W/m-K</td>
<td></td>
<td>Ultra-soft, Silicone, V-0</td>
</tr>
<tr>
<td>5592(S)</td>
<td>1.1 W/m-K</td>
<td></td>
<td>Soft, Silicone, V-0</td>
</tr>
<tr>
<td>5595(S)</td>
<td>1.6 W/m-K</td>
<td></td>
<td>Soft, Silicone, V-0</td>
</tr>
<tr>
<td>5514/5515(S)</td>
<td>1.6/3.0 W/m-K</td>
<td></td>
<td>Very Thin, Silicone, V-0</td>
</tr>
<tr>
<td>5516(S)/5519(S)</td>
<td>3.1/4.9 W/m-K</td>
<td></td>
<td>Soft, Silicone, V-0</td>
</tr>
</tbody>
</table>
## 3M™ Thermally Conductive Interface Thin Tape (50 um, 100 um, 200 um, 250 um)

<table>
<thead>
<tr>
<th></th>
<th>8802</th>
<th>8708-013</th>
<th>8805</th>
<th>8904-02</th>
<th>TM-670SA</th>
<th>8904-025</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Thickness (mm)</strong></td>
<td>0.05</td>
<td>0.13</td>
<td>0.13</td>
<td>0.2</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td><strong>Thermal Conductivity (W/m-k)</strong></td>
<td>0.6</td>
<td>0.6</td>
<td>0.6</td>
<td>1.5</td>
<td>0.6</td>
<td>1.5</td>
</tr>
<tr>
<td><strong>Adhesive Strength (90° peel) (Kg/inch)</strong></td>
<td>1.1 (180° peel)</td>
<td>4</td>
<td>1.6</td>
<td>2</td>
<td>3.5</td>
<td>2</td>
</tr>
<tr>
<td><strong>High temp stability(°C)-Long term</strong></td>
<td>90-100 °C</td>
<td>&lt;110 °C</td>
<td>90-100 °C</td>
<td>80-90 °C</td>
<td>&lt;110 °C</td>
<td>80-90 °C</td>
</tr>
<tr>
<td><strong>Flame retardant/UL</strong></td>
<td>NA</td>
<td>UL 94 FR V2</td>
<td>UL 746C*</td>
<td>UL 94 FRV0</td>
<td>NA</td>
<td>UL 94 FRV0</td>
</tr>
<tr>
<td><strong>Special characteristic</strong></td>
<td>Single liner, Thinner version of 88XX</td>
<td>Diff adhesion, Higher adhesion</td>
<td>Conformable</td>
<td>Not stretchable, Easy handling, High thermal K</td>
<td>Diff adhesion, Higher adhesion</td>
<td>Not stretchable, Easy handling, High thermal K</td>
</tr>
</tbody>
</table>
3M™ Thermally Conductive Heat Spreading Tapes (9876, 9877 and 9879)

Advantages

• Tapes designed to offer preferential XY thermal spreading vs. Z axis heat flow
• Cost effective “XY thermal flow vs. $$” in comparison to graphite type thermal spreading solutions
• Easy die cut to shape

Typical applications

• Thermal spreading on lighting and electrical recharger module, LED module board
• Thermal spreading of skins/cases of mobile, tablet, notebook and other consumer electronic devices
• Potential for thermal spreading on ECU, solar cell, 2nd battery assembly
3M™ Thermally Conductive Heat Spreading Tape (9876, 9877 and 9879)

Application consideration
• Target thermal performance in planar direction
• Application thickness (50 um, 80um, 100 um, 150 um & any custom thicknesses)
• E-grounding requirement
• Surface color requirement (Black, Brown, White and Pink)
• Single coated adhesion or double coated adhesion

Product list
• 9876B-05 (0.05 mm)
• 9876B-08 (0.08 mm)
• 9876-10(0.10 mm)
• 9876-15(0.15 mm)
• 9877-05( 0.05 mm) – Graphine powder coated for better thermal spreading
• 9879B-05X(0.05 mm) – E-grounding with a micro comply liner
3M™ Thermal Management Materials

Applications for Electrical Vehicle (EV) and Hybrid Electrical Vehicles (HEV)
1. Heat management between cells
   - Distributes heat generated in cells
   - Dielectric strength and long term stability

2. Thermal management between cells / case and heat sink
   - Dissipates heat between cells / case and heat sink
   - Dielectric strength and long term stability

3M™ Thermal Management Materials
EV & HEV Battery Assembly – Level One Solutions

3M™ Thermally Conductive Interface Pads
(5589H, 5590H, 5570, 5571, 5574, 5595S)
3M™ Thermal Management Materials
EV & HEV Battery Assembly – Level Two

3. Thermal management between cells / case and heat sink

- Dissipates heat of cells / case and heat sink
- Dielectric strength, anti-abrasion
- Cushioning / Damping
- Various thicknesses
- 3M™ Thermally Conductive Interface Pads 5589H, 5590H, 5571 and 5595S

PET film (22μm)

1.5mm t

3M™ Thermally Conductive Interface Pad (thickness: 1.5 mm)

Heat Sink Plate

Anti-Abrasions
3M™ Thermal Management Materials

EV & HEV Battery Assembly – Level Three

- Thermal management between cells
- Dielectric strength and high temp resistance
- 3M™ Thermally Conductive Interface Tapes (88XX series, 8940 and 8943)
- 3M™ Thermally Conductive Interface Pads

- Fixing battery cell and thermal management of Li-ion battery
- Low viscosity, lower curing, FR
- Dielectric strength, high temp resistance
- Adhesives, resin and potting types
- 3M™ Thermally Conductive Epoxy Adhesives (TC-2810 and TC-2707)
- 3M™ Thermally Conductive Polyurethane Potting Adhesive (TC-2920F)
3M™ Thermal Management Materials
EV & HEV Battery Applications – Level Four

• In-vehicle battery charger and motor assembly
• Low viscosity prior to curing
• Short curing time
• Good thermal K
• High temp resistance (120°C)
• Optional flame resistance (FR)
• High dielectric strength
• 3M new product initiative (potting)
# 3M™ Thermally Conductive Interface Pad 5517 (Clay Type)

## Features and Benefits
- Non-restorable shape
- Flexible to fit the space
- Excellent softness and conformability even to non-flat surfaces
- Surface tack allows pre-assembly

## Applications
- Gap filling
- Vibration damping and TIM

## Typical Properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness (mm)</td>
<td>1.0, 1.5, 2.0</td>
<td>-</td>
</tr>
<tr>
<td>Color</td>
<td>Sky Blue</td>
<td>Visual</td>
</tr>
<tr>
<td>Density</td>
<td>3.17 g/cm²</td>
<td>D6111*</td>
</tr>
<tr>
<td>Hardness</td>
<td>30-35</td>
<td>D2240* (Shore00)</td>
</tr>
<tr>
<td>Dielectric Strength</td>
<td>4.1 kV/mm</td>
<td>D149*</td>
</tr>
<tr>
<td>Thermal Conductivity (in-plane)</td>
<td>3 W/m-K</td>
<td>C1113* (Hot Wire)</td>
</tr>
</tbody>
</table>

*Tested in Accordance with ASTM*
# 3M Thermal Solutions for EV/HEV Applications

<table>
<thead>
<tr>
<th>Product Family</th>
<th>3M Product No.</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>3M™ Thermally Conductive Interface Tapes</td>
<td>8810, 8815 8940, 8943</td>
<td>Thin thickness available High temp resistance Long term stability</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3M™ Thermally Conductive Interface Pads</td>
<td>5570, 5574 5589H, 5571 5590H, 5567H 5578H 5595S</td>
<td>Good thermal conductivity Both acrylic and silicone resins available Various thickness PET/PI lamination options High temp/FR/dielectric strength/long term stability</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3M™ Thermally Conductive Polyurethane Potting Adhesives</td>
<td>TC-2920F NPI</td>
<td>Insulation Different curing profile High temp resistance (120~165°C) High dielectric strength</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3M™ Thermally Conductive Epoxy Adhesives</td>
<td>TC-2810 TC-2707</td>
<td>Good thermal conductivity Good bonding strength</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3M™ Thermally Conductive and Heat Spreading Tapes</td>
<td>9876 9877 9879</td>
<td>Good thermal spreading Lighter Thin thickness</td>
</tr>
</tbody>
</table>
# Features of Silicone Pad vs. Acrylic Pad

<table>
<thead>
<tr>
<th></th>
<th>Silicone Pad</th>
<th>Acrylic Pad</th>
</tr>
</thead>
<tbody>
<tr>
<td>Softness / Conformability</td>
<td>Excellent</td>
<td>Good</td>
</tr>
<tr>
<td>Thermal conductivity</td>
<td>Up to 5</td>
<td>Up to 4</td>
</tr>
<tr>
<td>Dielectric strength</td>
<td>Good</td>
<td>Excellent</td>
</tr>
<tr>
<td>Heat Resistance</td>
<td>Excellent</td>
<td>Good</td>
</tr>
<tr>
<td>Flame Retardancy</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>R/M Cost</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Key Advantage</td>
<td>HT Reliability / Softness</td>
<td>No Siloxane VOC &amp; No Oil Bleeding / Lower Cost</td>
</tr>
</tbody>
</table>

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Thank you
3M™ Thermally Conductive Interface Materials
Level Two Solutions (Heat Spreaders)

- Synthetic Graphite
- Metal Based
  - Heat spreading
    - Thin and various colors
  - Heat spreading + Heat insulating
  - Heat spreading + E-conductive
    - Heat spreading
    - E-grounding designed to protect circuits from static, surge, other e-shock etc.
    - Airless lamination with micro-comply liner (depending on user requirements)

- 3M™ Thermally Conductive and Heat Spreading Tape 9876
- 3M™ Thermally Conductive and Heat Spreading Tape 9877
- 3M™ Thermally and Electrically Conductive Hybrid Tape 9879