Non-Silicone, Thermal Interface Materials

Protect the heart of technology

AOS Thermal Compounds
ABOUT AOS

HISTORY
At AOS Thermal Compounds LLC, our roots trace back to Newark, New Jersey in 1895 and the founding of American Oil & Supply Co. AOS was a major supplier of lubricant products to the military in both World Wars and a pioneer in the development of turbine and hydraulic lubricants based on synthetic esters for aircraft, naval vessels and NASA.

*AOS developed the first non-silicone thermal grease.*

Our Mission
Our focus is thermal grease, and making it user-friendly. Our mission is to be the leading innovator in solving thermal interface challenges—*today and tomorrow.*

We are successful, profitable and constantly growing. Our people are focused, enthusiastic and committed contributors to a business driven by clients and product innovation.

Product Development
We focus our efforts not only to improve thermal conductivity, but can demonstrate superior shelf-life stability, long term performance and optimal rheological properties. AOS Thermal Compounds has added new analytical and testing capabilities to streamline our product development and quality control activities. We also employ statistical experimental design and molecular modeling in our product development methodology.

We are constantly striving to bring better solutions to the individual customer’s thermal management needs in today’s demanding environment.
SERVICES

Custom Formulation

AOS Thermal Compounds approaches our product development from a materials science perspective. We have combined knowledge gained from our experience in synthetic lubricants, metal oxide and ceramic fillers, plastics and resins, and surface science to develop new products designed to meet the ever-increasing demands of the thermal management market. We also have active programs to customize our existing products to meet individual customer needs.

Packaging

AOS offers a wide variety of packaging options. From standard tubes, jars, syringes, and cartridges; to single-use blister packs. We can assist in choosing a cost-effective packaging option that minimizes labor, handling and cleanup and is most appropriate for your application.

Bulk packaging in pails to drums is also available. And, with minimum orders, AOS will custom package material according to your specifications.

Dispensing

Applying thermal grease has never been easier. Let AOS introduce you to a variety of dispensing solutions using the manual or automatic dispensing equipment best suited for your application. Or try our sprayable thermal grease (Please call us at 888-662-7337 for spray instructions) or our line of Thermal Interface Materials for the greatest ease of handling and application. Whether applying grease manually or through an automated system, AOS will work with you to design and implement a quick and easy dispensing solution aimed at reducing cost, minimizing labor and eliminating mess.

Private Labeling

AOS Thermal Compounds offers private labeling services of our heat sink compounds to help compliment your existing product line. For more information regarding private labeling, please call a AOS Thermal Compounds representative at 888-662-7337.
**TERMINOLOGY**

1. **Heat Sink Compound:** A paste-like substance specifically engineered to be applied at an interface between a heated surface and the surface of a heat sink. It aids or speeds up the removal of heat from original surface (device) to another (heat sink). The device being cooled has more efficient operation and the useful lifetime is increased.

2. **Viscosity:** A measure of the resistance of a fluid-like material (such as thermal paste) to deformation by either a shear or tensile stress. It can be thought of as the “thickness” or “internal friction” of a compound to flow.

3. **Rheology:** The description of the flow characteristics of these highly filled paste-like solids in response to an applied force. They tend to be Newtonian or thixotropic in nature.

4. **Newtonian Flow:** Material flow is determined by only by its viscosity at a given temperature and tends to be independent of the shear force applied. The viscosity does not change in response to an applied force (stress). Newtonian fluids can be characterized by a single coefficient of viscosity for a specific temperature. Examples of this behavior are honey and higher molecular weight silicone fluids.

5. **Thixotropic:** A material’s flow is very much dependent on the shear or tensile stress applied. The coefficient of viscosity tends to decrease as the applied force is increased. Examples of this behavior are toothpaste, peanut butter, and mayonnaise.

6. **Bond Line:** The limiting or minimum thickness that an interface material where a minimum thermal resistance is achieved. The thermal resistance will not change at thicknesses less than this value.

7. **Dielectric strength:** Dielectric strength is defined as the maximum voltage required to produce a dielectric breakdown (electric current flow) through the material. It is expressed as Volts per unit thickness. The higher the dielectric strength of a material, the less able it is to conduct an electrical current. A common accepted measurement technique is the ASTM D 149 method.

8. **Electrically conductive:** Sometimes is referred to as specific conductance. It is a measure of a material’s ability to conduct an electric current. Most pastes are magnitudes less electrically conductive than metallic copper or aluminum wire. Pastes containing ceramics and metal oxides are electrically non-conductive. Even those containing metallic particles are essentially electrically non-conductive compared to copper wires and vias. Problems arise when metal particle containing pastes break down and particles migrate onto the surfaces of devices causing short circuits.

9. **Outgassing:** Refers to trapped gas being released from a solid when it is heated and/or placed under a vacuum. Typically, this is an important property for silicone fluid based thermal compounds. The volatile components released with many silicone fluids tend to cloud optical surfaces. This is much less prevalent with non-silicone fluid-based materials. Outgassing is often tested by the ASTM E 595 method. This test consists of the application of a vacuum of 10-5 torr, at 100 °C, for 24 hours. The collected volatile condensed material (cvcm) and the total mass loss (tml) are measured using this method.

10. **Units of Thermal Conductivity:** Currently given in W/m-K (Watts/meter-degree Kelvin). Older literature values may be reported in cal/(cm2)/sec/cm°C. For example, copper has a value of 0.94 cal/(cm2)/sec/cm°C = 394 W-m/K.

11. **Pump Out:** This is a phenomenon that occurs with lower viscosity materials, such as thermal greases, where the interface material appears to ooze or migrate out from between two surfaces after a period of use. It is believed to occur because the material is successively stressed mechanically due to changes in temperature. As a result, the two surfaces expand and contract at different rates; stressing the material and causing component separation. Small mechanical deformations occur when electrical current passes through the device.
Thermal Conductivity vs Thermal Resistance

It is critically important to understand the difference between bulk conductivity (W/mK) and contact resistance (°C/W) to fully understand overall thermal performance when selecting thermal interface materials (TIM’s). Bulk thermal conductivity is a measurable physical property of a material much like boiling point, where thermal resistance is a measurement of heat transfer across a construction of interfaces from point A to point B. Quite often engineers look for the most conductive TIM without regard for other properties such as wetting and bond line thickness (BLT). Material rheology, modulus, filler size, shape and content all play a critical role in determining improved surface wetting and BLT. Ideally a TIM for low BLT will fully wet, but allow intimate contact of the adjoining surfaces (where the best heat transfer takes place), and then displace the air and fill the microscopic voids. Therefore, a modest bulk thermal conductivity TIM may exhibit a lower thermal resistance than a high conductivity TIM that may have poor wetting and/or large particles. However, high thermal conductivity becomes much more important for thick grease applications or gap fillers where there is no intimate contact of the adjoining surfaces and the heat must travel a longer path through the TIM. Note: Thermal Impedance incorporates area into the thermal resistance calculation and is expressed as °C in²/W or °C cm²/W.

1. ASTM-D5470-12: Tests thermal conductivity
2. ORACLE® 270-7806-01 TTV: Tests thermal resistance
**TESTING METHODS**

**ASTM-D5470-12**: Lab controlled thermal resistance tester used for determining TIM bulk thermal conductivity (W/mK).

This is a steady state method of determining the thermal conductivity of a substance. The thermal resistance (more specifically referred to as thermal impedance) for a material, at a given thickness, is determined by placing the paste at the interface between equilibrated hot and cold blocks. The heat flow through the material is determined by measuring the temperature gradient set up between the two blocks at steady state. The temperatures are determined at set placements along the hot and cold gradients as shown in the following figure of an actual trace obtained on an ASTM D-5470-12 flow apparatus here at AOS.

**Thermal conductivity** for a material is determined (back calculation) by determining the inverse of the slope of the graph of several thermal impedances (resistances) at various thicknesses. The graph below shows the results taken at 1, 2, 5 and 20 mils (0.001” = mil).

**AOS Thermal Compounds does internal thermal testing as well as outside third party testing to confirm results. We are also pleased to offer thermal testing services, including TIM life cycle testing.**
The average temperature of a specific area on the die corresponding to an average resistance measurement is determined using a calibration chart. The chart is developed from die resistances recorded at a number of set temperatures as shown below.

The power supplied to the TTV is carefully recorded also. The resistance is determined using the fundamental equation $(T_r - T_a)/P$. 

**ORACLE® 270-7806-01 TTV:**
In situ thermal resistance tester for determining comparative TIM thermal performance in “real world” integrated circuits.

**The Thermal Test Vehicle (TTV)** is used to provide a thermal resistance on a device that is closer to real-world applications. It consists of a ca. 1” x 1” bare silicone die and a copper heat sink. The copper heat sink has an embedded T type thermocouple that measures the temperature of the heat sink. The silicone die has 34 thermal sensors across the area of a die that measure the resistances in response to the build up of heat. 0.5 grams of thermal grease is applied between the die and heat sink and a uniform power is supplied across the die. The resistances of an area on the die and the heat sink temperature are recorded after the power is applied and temperature equilibrium is established. The temperatures and resistances are recorded in an Excel file as shown.
The thermal resistance is often of greater importance than the thermal conductivity for determining how effective a TIM will be in an application where the gap is thin.

### AOS MATERIALS TESTED AGAINST LEADING COMPETITION

<table>
<thead>
<tr>
<th>Material</th>
<th>Thermal Resistance Rank</th>
<th>Thermal Resistance °C/W</th>
<th>Thermal Conductivity Rank</th>
<th>Thermal Conductivity W/m-K</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AOS 52054</strong></td>
<td>1</td>
<td>0.031</td>
<td>5</td>
<td>1.3</td>
</tr>
<tr>
<td>Company A</td>
<td>2</td>
<td>0.032</td>
<td>4</td>
<td>2.8</td>
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<tr>
<td>gray silicone thermal grease</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Company B</td>
<td>3</td>
<td>0.035</td>
<td>3</td>
<td>3.6</td>
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<tr>
<td>gray silicone thermal grease</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Company C</td>
<td>4</td>
<td>0.038</td>
<td>6</td>
<td>1.2</td>
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<td>over-clocker grease</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>AOS 54011 (High Temp)</strong></td>
<td>5</td>
<td>0.041</td>
<td>7</td>
<td>0.9</td>
</tr>
<tr>
<td>Company B</td>
<td>6</td>
<td>0.046</td>
<td>2</td>
<td>4.4</td>
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<tr>
<td>gray silicone thermal grease</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>AOS 52070</strong></td>
<td>7</td>
<td>0.048</td>
<td>1</td>
<td>7.0</td>
</tr>
<tr>
<td>Company A</td>
<td>8</td>
<td>0.054</td>
<td>8</td>
<td>0.7</td>
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<tr>
<td>standard white silicone grease</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td><strong>AOS MICRO-FAZE® (Thermal Pad)</strong></td>
<td>9</td>
<td>0.062</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Company D</td>
<td>10</td>
<td>0.114</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>typical PCM</td>
<td></td>
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</tbody>
</table>

Data compiled on ASTM-D5470-12 and TTV at AOS Thermal Compounds.
PRODUCT STABILITY

Company A: Standard White Thermal Grease

- Zero cycles
- After 300 cycles: Thermal grease voids and pumps out

AOS 52054 Thermal Grease

- Zero cycles
- After 300 cycles: Remains tacky with zero pump out

AOS Micro-Faze 3 A6 Thermal Pad

- Zero cycles
- After 300 cycles: Remains tacky with zero pump out

165 - 0 °C @ 10 minute dwell
MICRO-FAZE® is a new, revolutionary thermal interface film formulated with non-silicone thermal grease. It was developed by AOS to offer the lowest thermal resistance in a thermal interface without the mess of grease. MICRO-FAZE® does not require burn-in to form into place.

Technical Advantages
- Low thermal resistance with minimum force
- Naturally tacky, non-silicone
- Conforms with coefficient of thermal expansion (CTE) differences
- Uniform film and exact thickness of thermal grease with each application
- No phase change required for heat transfer to take place—Good Low Temp Performance
- Durable resistance over usable lifetime
- Easily stored at a wide range of temperatures

What is MICRO-FAZE®?

A Based on Aluminum Carrier
- A4 (2.0 W/m-K @ 55°C)
- 3 A6 (5.0 W/m-K @ 55°C)
- 0.8 mil grease
- 2.0 mil aluminum
- 0.8 mil grease

K Kapton MT where electrical resistance is required
- K6 (1.0 W/m-K @ 55°C)
- 1.8 mil grease
- 2.0 mil Kapton
- 1.8 mil grease

RESISTANCE OVER USABLE LIFETIME IS NOW ESSENTIAL
Features & Benefits

- Retains all the performance advantages of thermal grease but in the form of a thermal pad
- Requires minimum force to achieve total interface contact
- Allows for total “wetting action” to fill all microscopic surface voids without changing phase
- A positive coefficient of thermal expansion (CTE) increases the wetting action for total interface contact
- Heat transfer takes place at any temperature (unlike phase change materials), making MICRO-FAZE® an excellent choice for cold plate applications
- Offers maximum heat transfer capability for power components
- Excellent replacement for phase change materials and silicone pads
- Is a “drop-in-place” product that is easy to use and handle in a manufacturing environment
- Naturally tacky—no adhesive, fiberglass or other non-conductive material is used that may penalize thermal resistance
- Microscopically changes to fill all microscopic voids on part surfaces
- **DOES NOT PUMP OUT!**

Used in All Electronics Cooling Assemblies

- IGBT
- Uninterrupted Power Supply
- LED’s
Thermal Grease Performance in a Thermal Pad

- MICRO-FAZE® performs well at any temperature and minimal pressure

**MICROFAZE® SERIES AT 55°C**

- ASTMD 5470-12 thermal resistance values at pressures ranges from 10psi to 100psi

**Samples After Thermal Shock Stability (0—165°C @ 10 min Dwell)**

- Leading phase-change material after 20 thermal cycles
- Contact lost; dried out
- MICROFAZE® 3 A6-52061 after 150 thermal cycles
- Remains tacky with zero pump out
**Independent Material Testing**

**Experiment:** Materials tested at different torque values

**Summary:** Grease performed best; Micro-faze 3 A6 slightly better than leading Phase Change material

- Actual Thermal Images @ 26 ft-in torque; Equilibrated @ 38 amp, 1.6 volts

**AOS MICRO-FAZE 3A4**

- Performance maintained over time

**Leading Phase Change**

- Phase change degradation and pump out lead to over-heating and component failure

**THERMAL IMAGING DETAILS**

Sample Tested © several torques and power settings on a 12 pin 44 x 33 mm SiC module

- Max Equilibrium Temperature MF 3 A6 and Phase Change; Settings for both = 221°C @ 231 watts
- Initial ΔT’s of 10.7 and 11.2 °C, respectively at 12 in-lb torque
How MICRO-FAZE® Works

• MICRO-FAZE® grease is comparable to leading CPU grease

• Pad form demonstrates superior resistance to leading CPU thermal grease

![THERMAL TESTER RESISTANCE RESPONSE](image1)

![MICROFAZE® RESISTANCE](image2)
MICRO-FAZE® thermal pads are supplied in bulk rolls, sheets, individual die-cut parts or kiss-cut rolls with pull tabs for ease of application.

### Configuration

- Bulk rolls and sheets
- Die-cut to exact specifications
- Kiss cut with tabs

### Physical Properties

<table>
<thead>
<tr>
<th></th>
<th>A4</th>
<th>K</th>
<th>3A6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Substrate</td>
<td>Aluminum</td>
<td>Kapton®</td>
<td>Aluminum</td>
</tr>
<tr>
<td>Substrate Thickness, in.</td>
<td>0.002</td>
<td>0.002</td>
<td>0.002</td>
</tr>
<tr>
<td>Compound Thickness/side in.</td>
<td>0.001</td>
<td>0.002</td>
<td>0.002</td>
</tr>
<tr>
<td>Total Thickness, in.</td>
<td>0.004</td>
<td>0.006</td>
<td>0.006</td>
</tr>
</tbody>
</table>

### Thermal Properties

<table>
<thead>
<tr>
<th></th>
<th>A4 0.20-0.10</th>
<th>K 0.55-0.48</th>
<th>3A6 0.12-0.06</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal Resistance, @ 55°C in²/W 10 PSI to 70 PSI Test Method: ASTM D-5470-12</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dielectric Constant, @ 1 KHz Test Method: ASTM D-150</td>
<td></td>
<td>3.7</td>
<td></td>
</tr>
<tr>
<td>Volume Resistivity, ohm-cm ASTM D-257</td>
<td></td>
<td>1.01x1015</td>
<td></td>
</tr>
</tbody>
</table>
Product Description

SURE-FORM® Non-Silicone Thermally Conductive Gap Filler was developed by AOS in response to the growing demand in electronics for increased thermal transfer efficiency in applications where surface textures vary and the space between surfaces is uneven.

SURE-FORM® is highly conformable and is an excellent replacement for silicone elastomer gap fillers, which require significant pressure to achieve 100 percent surface contact. SURE-FORM is easy to use and offers all the benefits and performance of thermal grease without the limitations in application and handling.

Technical Advantages

• High performance gap-filling pad
• Easily conforms to uneven surfaces with minimal pressure
• Will not melt, flow or drip
• Naturally tacky and reworkable (in sheet form)

What is SURE-FORM®?

| Product Code | Description | Thermal Conductivity
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>52041 SHEET</td>
<td>Clay-like material, available in sheet form</td>
<td>2.2 W/m-K @ 36°C 60 – 250 mil thickness</td>
</tr>
<tr>
<td>52153 PUTTY</td>
<td>One-part dispensable, high thermal conductivity</td>
<td>3.5 W/m-K @ 36°C 1-part dispensable</td>
</tr>
<tr>
<td>52070 PUTTY</td>
<td>Highest performance, one part gap filler</td>
<td>7.0 W/m-K @ 36°C 1-part dispensable</td>
</tr>
</tbody>
</table>
Features & Benefits

- **SURE-FORM®** retains all the unique advantages of thermal grease but in the form of a gap filler material
- **SURE-FORM®** is a highly conformable, soft, naturally tacky gap filling material for use in applications where minimum stress is placed on components
- **SURE-FORM®** will conform to any shape and/or size of a component enabling complete physical contact, so as to minimize the resistance to heat flow and to achieve the best thermally conductive path
- The natural tackiness of **SURE-FORM®** allows two surfaces to be in contact with minimum pressure

Suggested Applications

- **SURE-FORM®’s** highly conformable nature allows the pad to fill all voids between a heat generating device and heat sink metal chassis
- Non-Silicone formula is advantageous for optical applications and high compression loads
- **SURE-FORM®** conducts heat away from individual components and into metal covers, frames or spreader plates
- **SURE-FORM®** offers unique advantages in applications such as microprocessors, cache chips, heat pipe interposer plates, laptop PCs, high-density handheld portable electronics, electronic ballasts & various automotive applications

- Automotive
- Battery
- Lighting
• ASTMD 5470-06 thermal resistance values at pressures ranges from 10psi to 100psi

52153 PUTTY
3.5 W/m-K 36 °C 1-part dispensable

• Samples after 20 thermal shock cycles

• SURE-FORM® 52153 unchanged

• Silicone Putty—Fluid bleed and slump
**Distinct Conformability**

- **SURE-FORM®** is available in sheets and can be die-cut to exact specifications ranging in thickness from 0.04" (1.0mm) and higher
- Naturally tacky and reworkable

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**High Thermal Conductivity**

- **SURE-FORM®** is also available in standard grease form
- Cost effective
- Highest performance, one-part gap filler
**Product Description**

Since developing the first non-silicone thermal grease for AT&T in the early 1970’s, AOS has continued to develop and expand the widest offering of silicone-free thermal greases on the market, all with a design toward ease of use and durability. There is no silver bullet thermal grease that is ideal for every application. This is why we offer such a wide variety from low resistance thin bond line products, to high thermal conductivity greases for thick film applications. Typical properties can include water cleanability, thixotropic or Newtonian rheology, customized rheology, little to no pump-out, low outgassing, and high temperature stability.

**Silicone vs Non-Silicone**

- Silicone oils tend to bleed which lends to migration and contamination
- Silicone contamination can lead to local component, board, assembly or even plant wide problems with surface modifications and applications such as solder, adhesives, paint, ink, etc.
- Silicone oil bleed can lead to dry-out, cracking and the formation of air gaps in the interface

- Non-silicones are not a single fluid but a mixture of synthetic oils, vegetable oils, surfactants, tactifying resins and thermoplastic elastomers
- Non-silicone thermal greases remain tacky and in place for the operational life or your hardware

**100 Thermal Shock Cycles, 165°C to 0°C**

- Silicone grease voids and pumps out
- AOS Non-silicone; no voids or pump-out