Understanding Differences Between Thermal Interface Materials: Improve your ability to specify the optimum TIM

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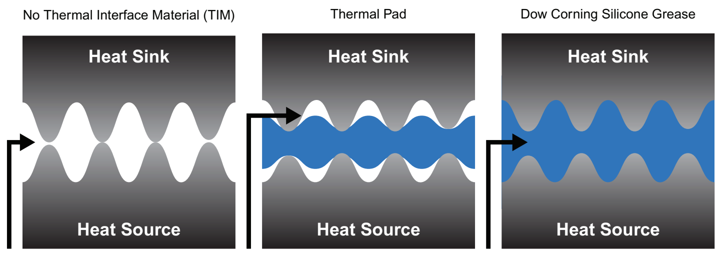
Thermal interface materials come in a wide variety of product types and price points. Having a basic understanding of their strengths, weaknesses, and applicability is key to successful selection of the best interface material for your application needs. This paper will explain the key differences between thermal greases, phase change materials (PCMs), thermal pads and films, adhesives, and alloy composite materials. This document is part three in a three-part series. Previous installments dealt with thermal performance data and non-thermal material property impacts on thermal performance.



Micro-gaps or surface roughness prevent effective heat transfer potentially leading to device failure.

Non-flowable solutions such as thermal pads leave voids that inhibit heat transfer.

Grease matrices completely fill micro-gaps to ensure heat flow away from vital parts.

Greases enable thinner bond lines, further reducing thermal resistance.

Thermal Greases

Also known as thermal compounds, thermal greases are made up of a non-curing polymeric matrix to which conductive filler particles are added to make the compound thermally conductive. The term “grease” refers to the fact that the matrix does not cure and retains its liquid or grease-like properties indefinitely.

Thermal greases offer the best overall performance of any of the standard thermal interface materials currently on the market. This is due to the ability of a grease to flow into any nook or cranny of the intended application and conform to a wide range of surface roughness present on any housing, heat spreader, or heat sink surface. The following diagram illustrates the difference between the ability of a grease and a thermal pad to overcome surface roughness on a heat sink.

Other key advantages of greases over competing interface material solutions are cost, reworkability, low thermal resistance, and the ability to form ultra-thin bond lines (7 – 20 microns). Since thermal greases do not need to be coated and cured into a sheet and then cut to shape, manufacturing costs are comparatively low. Because they do not cure, thermal greases can easily be wiped clean from the surface of defective parts for rework, using a clean rag or aided by ozone-safe methylsiloxane fluids. When using optimized filler particle sizes, greases can also achieve thinner bond lines than other traditional TIMs, helping to further reduce thermal resistance.

Disadvantages to thermal greases most often arise from their uncured state. With some formulations, the material may not stay in place if the device is mounted vertically, or if the grease is applied in ultra-thick bond lines. Some materials can be subject to migration over time, as a device heats up and cools during operation, creating a pumping effect due to coefficient of thermal expansion (CTE) mismatches.

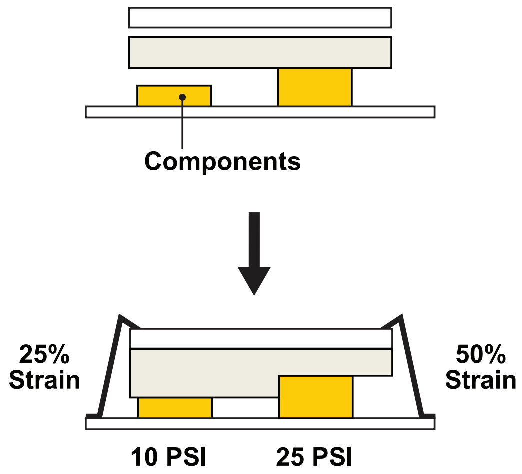
Over the last few years, material vendors such as Dow Corning have successfully developed thermal greases that can be vertically mounted and used in thick bond line applications. Recent developments have also been successful at minimizing or eliminating the typical pump-out phenomenon common to older grease technologies. Grease materials have been successfully specified into servers, desktops, and notebook CPUs in the computer industry. They are also widely used in displays, automotive control units, and communications equipment. Typically, greases are specified when an application demands high performance and thin bond lines.

Thermal Pads and Films

Often called gap pads or elastomeric pads, thermal pads and films are made by curing a ceramic-filled polymer system into a pad or film to a specified thickness on a coater. The material is sold in rolls or sheets directly to a customer or sent to a converter who stamps out specific part shapes designed for the intended application. Thermal pads are soft, compliant materials based on a gel-like polymer system intended to fill air gaps between components and a housing or chassis. Thermal films and elastomeric pads cure into a hard rubber type of material and often have a dual purpose: to act as a dielectric barrier and a thermal interface material in power components such as transistors.

Pre-cured thermal pads are often employed to overcome unanticipated design problems, and can be very effective at covering a PCB board populated by a variety of components with varying heights. Because the thermal material is cured, there is no concern about contaminating other components. On the downside, thermal pads are often more expensive on a per-unit basis than a wet dispensed material and typically cannot offer the same level of thermal performance.

When specifying thermal pads, it is very important to pay attention to the compressibility of the material. If an engineer is trying to use a thermal pad to protect two different components of varying heights on the same PCB, care must be taken that the compressive force on the taller component does not exceed the maximum allowable pressure of the component and that sufficient force is applied to ensure contact with the shorter component for effective heat transfer. Consider the following diagram:

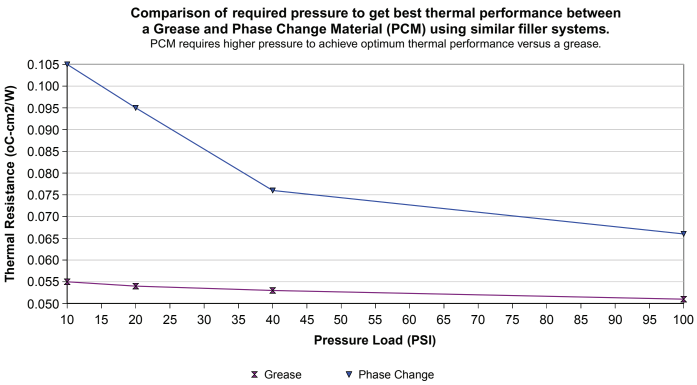


In the example above, 25% compression is required to contact the 10 psi component, but this requires 50% compression of the portion of the pad protecting the component with a 25 psi limit. Thermal pad suppliers often provide stress strain curves which detail how much pressure it takes to compress the thermal pad a given percentage. The engineer in the above example can simply look at the vendor data to ensure that 50% compression does not exceed 25 psi when selecting a material. In general, the more compressible the thermal pad, the lower the contact resistance, the lower the stress, and the better the performance. Thermal pads are effectively employed in a wide range of low thermal demand applications such as disk drives, chipsets, communication equipment, and general PCB board protection.

Phase Change Materials

Phase change materials (PCMs) are designed to offer the thermal performance of greases, with the advantages of pre-cured thermal pads, in a single material. In principle, a phase change material is a solid at room temperature and then as the device heats up, the PCM changes from a solid phase to a flowable phase, where the material can fill in all the surface roughness similar to a grease. As the material cools, it solidifies again. Phase change materials use special waxes that are designed to “melt” or change phases at the expected operating temperature of the device, along with filler systems similar to those used for thermal greases, pads, and films.

Phase change materials offer a good compromise on performance and handling, but still cannot duplicate the performance of thermal greases. One reason for this is that phase change materials require a high amount of pressure to achieve the same level of thermal performance as a grease, and this pressure limits their applicability in sensitive designs. The figure below shows the thermal resistance (y-axis) as a function of pressure in psi (x-axis) for a typical PCM. Note that the lowest thermal resistance is not achieved until an applied pressure of >80 psi is reached. This problem is magnified by the fact that phase change materials tend to be much harder than thermal pads, and thus the pressure required to meet thermal targets often presents a mechanical challenge for design engineers.



Phase change materials are widely used for memory modules, graphics chips, and notebook computers. Due to the manufacturing costs associated with coating and converting, along with the unique phase-change waxes, PCMs tend to be higher priced than thermal pads and films, but can offer better thermal performance than either of those options.

Phase Change Materials

Greases, pads, films, and PCMs account for more than 75% of the thermal interface market, although alternatives such as thermally conductive adhesives, polymer solder hybrids, and metal composites are increasing in use. Thermal adhesives find application as conductive lid seals, TIM 1 between chips and lids, or for affixing heat sinks to heat generating devices. A wide range of bulk thermal performance capability can be found in these materials, from 0.5 W/mK to >6W/mK. Adhesives generally fall into two classes: those designed to mechanically fasten parts and eliminate screws or other clamping devices and adhesives used to achieve intimate contact with mating surfaces without delamination to ensure long-term performance.

Polymer solder hybrids and metal matrix TIMs are most often found in high-end processor chip packaging. Their cost limits their use to highly specialized chips. Polymer solder hybrids are available in the form of greases, PCMs and pads. In addition to using standard ceramic fillers such as alumina and boron nitride, material designers add metal alloys or solders to further improve thermal performance, giving these hybrids their name. Metal matrix TIMs or metal pre-forms are pre-stamped sheets of highly conformable metal such as indium or an alloy of indium, such as IAg or ISnBi. These solutions offer a great balance between high thermal performance and mechanical performance but are more than five times the cost of standard TIM materials. They typically require special processing equipment and steps to incorporate them into the thermal design, giving them limited applicability to the general thermal market.

Dow Corning offers a complete line of thermal interface materials, backed by a global application engineering team skilled in the art of thermal measurement, material selection, and application testing. For more information on Dow Corning Thermal Interface Materials, please visit us at www.dowcorning.com/electronics or contact your local Dow Corning Distributor.

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