WHITEPAPER

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TAPE INNOVATIONS

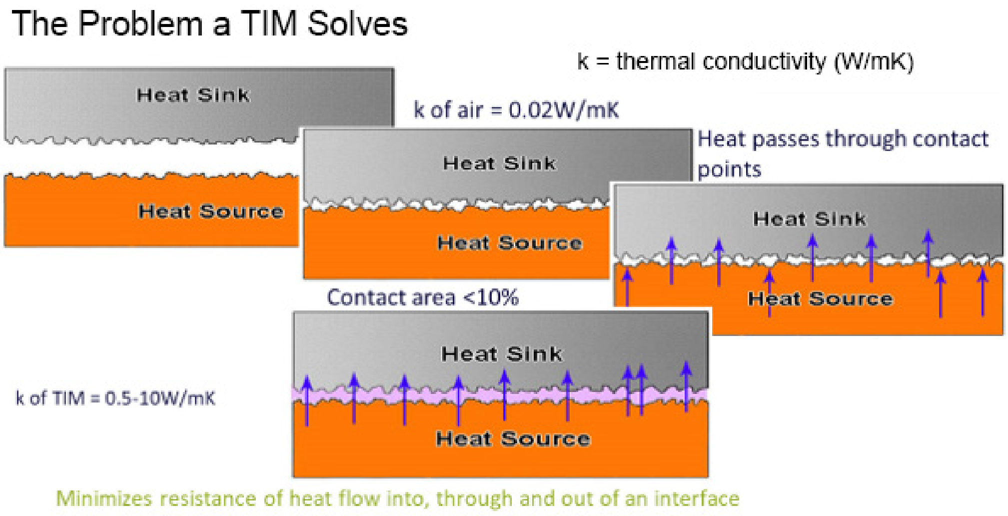
How to Choose the Right Thermal Interface Materials: Types, Compounds and Specifications

Designers know that electronics dissipate heat, and certain components can rise to unacceptably high temperatures. In some application areas like 5G telecom infrastructure, modern data center infrastructure, and automotive power management, excessive heat can disable a system, forcing designers to innovate novel cooling solutions for their systems. More of these systems are being packaged in enclosures with aggressive form factors, which makes implementation of large heat sinks and fans very difficult or infeasible. Thermal interface materials are one of the tools available to designers to help transport heat away from critical components, particularly when forced airflow is unavailable.

As more electrical designers contend with form factor and heat dissipation challenges, they may not be familiar with the range of thermal interface material options on the market, or how to select the right mix of materials to solve specific design challenges. Laird Performance Materials provides multiple thermal interface material options that can help designers solve complex thermal challenges. These solutions are applicable for use in automotive, telecom, data center, and power conversion systems, as well as in many other markets. In this whitepaper, we will explore the range of thermal interface materials on the market, as well as some of the design goals to be achieved when selecting these materials.

Why Designers Need Thermal Interface Materials

Thermal interface materials are intended to provide uniform thermal contact between two mating surfaces, typically a component and its heat sink. In the past, systems designers would typically use a fan, heat sink, or both as a cure-all for most cooling problems on specific components. This was because most of the heat was generated in bulky power supplies or large CPUs, both of which were large enough to accommodate such cooling measures. Even in modern systems where forced airflow across a heat sink is present, there remains the problem of quickly dissipating heat away from a hot component and into the heat sink. Thermal interface materials provide a solution by filling gaps between machined surfaces, ensuring uniform contact and high heat transfer efficiency. The same idea applies when the enclosure acts as the heat sink.



Thermal interface materials are sometimes generically called “gap fillers” as they fill in small air gaps between machined surfaces, as shown in the above graphic. By adding a material to fill gaps between machined surfaces, a path to a heat sink with low thermal resistance is created. With the appropriate thermal interface material, heat sink, and path for natural or forced convection, the target component’s thermal resistance to ambient can be reduced.

The challenge for many designers is comparing thermal interface materials for use in bonding components to heat sinks, components to enclosure elements, or a board to an enclosure.

▪ Types of Thermal Interface Materials and Compounds

Thermal gap fillers come in solid and liquid forms, allowing them to be incorporated in different processes while satisfying diverse product performance requirements. The gap filler materials shown below are intended for interfacing between a hot component and a chassis, or between a hot component and a heat sink.

▪ Liquid-dispensable Gap Fillers

These materials are better-known as thermal pastes, thermal putty, or sometimes thermal grease, with some manufacturers using these terms interchangeably. These materials are dispensed directly on a component and can be applied very quickly using automated processing. . Liquid gap fillers are typically made up of a resin system blended with ceramic, metal or metal oxide fillers, which gives these materials their competitively high thermal conductivity. Liquid gap fillers are ideal for applications that require high conformability at low pressures and low steady state stress. Cure in place options can also be a consideration for applications that require improved reliability.

▪ Thermal Greases and Phase Change Materials

Other types of thermal interface materials include thermally conductive greases and phase change materials (PCMs). These differ from gap fillers in that they are used generally in applications with a thin bond line, typically 50 microns or less, where the meeting surfaces are relatively flat. These types of materials do not fill a significant gap within the application. The main function of these grease and phase change material TIMs is to wet the surfaces of the heat source and the heat sink to intimately interface those two surfaces together. Generally, these materials are used in applications with a constant applied pressure. Typically greases flow and wet surfaces at room temperature, where phase change materials require the device to be heated in order to flow and wet the surfaces.

▪ High Thermal Conductivity PCB Laminates

When some PCB designers think of high thermal conductivity laminates, they tend to look to metal core or ceramic constructions. Newer advanced resin systems can provide higher thermal conductivity than standard FR4-grade laminates but without the manufacturing difficulties of those alternative stackups. When used as a thermal interface material, these laminates can provide high heat transfer to an enclosure through direct conduction, or through another thermal interface material like a solid thermal pad. Possible application areas include automotive power systems, backplanes, and industrial electronics.

▪ Thermal Pads

Thermal pads, sometimes referred to as Gap Fillers are a class of TIMs that fills “a large gap” between heat-generating and heat-dissipating surfaces. Often thermal pads are used to cover multiple heat sources within an application and interface them to a common heat sink. A gap filler is expected to be compliant enough to deflect to accommodate multiple module heights and tolerance variations within applications without generating excessive levels of pressure within the system. These materials are usually supplied as die cut parts between release films, on a roll, or in sheets. These materials come in various compositions:

- Silicone or Paraffin wax-based filled materials that provide properties such as excellent surface wetting, high thermal stability, flexibility, and physiological inertness.
- Electrically insulating materials for use when ESD and isolation are concerns.

- Graphite-based materials that provide high overall conductivity, particularly in-plane conductivity for use on larger components.

Specifying Thermal Interface Materials

There are several material specifications that apply to thermal interface materials. The thermal conductivity of the material or the thermal resistance of the supplied product are a primary material property to consider as this value can be used as a design target in simulations or some basic calculations.

Many products require consideration of electrical and mechanical properties for use in their desired application. These include:

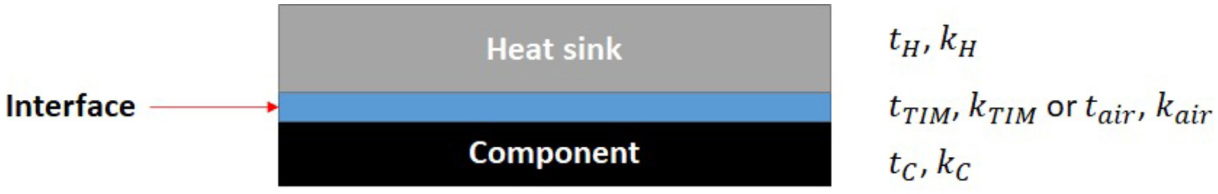
- **Breakdown voltage and resistivity:** These are important for insulating thermal interface materials that will be used in high-voltage systems.
- **Young's modulus:** Some materials can provide a damping effect against vibration, so the mechanical properties should be considered when selecting materials.
- **Temperature stability:** Thermal interface materials should be reliable over a broad temperature range to ensure reliable thermal properties and premature degradation.
- **Dielectric constant:** This is important for thermal pads that will attach to a PCB as the presence of a dielectric can modify the impedance of high-speed/high-frequency transmission lines. The dielectric constant can also influence radiated EMI from a heat sink.

In addition to material properties, designers should consider automated assembly processes and the ease with which certain solutions can be integrated into a PCBA or enclosure during manufacturing. The above list of thermal interface materials come in solid and liquid forms, giving designers some flexibility to choose the material that will work best for their components, application, and assembly process.

Designing With Thermal Interface Materials: An Example

Because heat sinks and active cooling designs can involve many simulations, it's easy to assume that the same applies to the use of thermal interface materials. In reality, design calculations for a system with a heat sink and a thermal interface material are rather simple and follow some basic analogies from circuit analysis. The central idea is to calculate the thermal resistance of the stacked component + interface + heatsink system and compare this to a component + air + heatsink system. By considering the relative thermal conductivities of an air-gapped interface, one can calculate the expected reduction in the thermal resistance to ambient value for a component with an attached thermal interface material and heat sink.

The system with a heat sink, component, and interface between them can generally be treated as a multilayered system with 1-D heat transfer. Using the bulk conductivity relationship for layered materials, the thermal resistance of a system with air can be compared with a system containing the thermal interface material. The thermal resistances of each system are defined below:



$$R_{air} = \frac{t_H}{Ak_H} + \frac{t_{air}}{Ak_{air}} + \frac{t_C}{Ak_C}$$

$$R_{TIM} = \frac{t_H}{Ak_H} + \frac{t_{TIM}}{Ak_{TIM}} + \frac{t_C}{Ak_C}$$

By subtracting the two thermal resistances, one can arrive at the following relation for the expected change in the thermal resistance to ambient by adding the thermal interface material:

$$R_{TIM} - R_{air} = \frac{t_{TIM}}{Ak_{TIM}} - \frac{t_{air}}{Ak_{air}}$$

Typical TIM:air thickness ratios in the above system are anywhere from 10:1 to 1000:1, depending on the surface roughness of the machined heat sink and attachment surface on the component. By comparing with a material with a 0.5 mm thermal pad with thermal conductivity of 3.5 W/(m·K), one finds that the expected reduction in thermal resistance to ambient for the bottom component is approximately -3.81 °C/W for a 5 mm × 5 mm integrated circuit.

This is a rough approximation, but it illustrates how various factors in a component and its heatsink affect heat transport and a possible change in the thermal resistance to ambient for the target component. This leaves a designer with three important points to consider when selecting a thermal interface material for a heat sink attachment:

1. Thermal conductivity: Using a material with higher thermal conductivity reduces the overall thermal resistance of the TIM.
2. TIM Thickness: Using a thinner material will provide a lower thermal resistance.
3. Application Area: Using a larger area will result in a lower thermal resistance.

Contact Laird for High-Performance Thermal Interface Materials

With electronic designs constantly shrinking to smaller form factors, being integrated into an enclosure, or taking the place of active cooling measures, designers need solutions to help them efficiently transfer heat away from critical components. Laird's line of thermal interface materials includes many options targeting various form factors, packaging requirements, and assembly processes. Designers can mix and match Laird's thermal interface materials to target multiple heat sources in complex systems, giving designers the flexibility they need to implement innovative cooling solutions in their systems.

Contact Laird today to learn more.