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Selection of thermal interface materials (TIM)

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Knowledge of the requirements of your application is the key to choosing the correct thermal interface materials

When it comes to choosing the correct thermal interface material (TIM), many people are unsure of what to look for. In this article we would like to provide you with everything you need to know about thermal interface materials.
As soon as the performance of the components increases, the cooling requirement increases accordingly. As a rule of thumb, the failure rate is duplicated with every 10 ° C increase in junction temperature. As a result, the heat from the hot chips has to be dissipated to the current of the ambient air.

The demand is considerable, so that a variety of new heat management systems have been developed. Almost all of them still use thermal interface materials (TIMS), which should enable the effective flow of heat through the appropriate interfaces of cooling systems.

The main task of TIMs is to guarantee effective heat transfer from hot chips to dissipation devices such as heat sinks or spreaders. As the heat flows, it repeatedly encounters resistance that complicates and hinders the overall heat transfer. TIMs help overcome the most problematic resistance. We are talking about the contact resistance between the counterparts (heat source - heat sink). Because air gaps reduce the heat flow from the hot component to the sink or the spreader to a large extent. Effective TIM replaces the existing gaps caused by the non-smooth fitting surfaces. This is done with the help of special material; whose thermal conductivity is significantly greater than that of air. The poor conduction of point contacts and air is replaced by a significantly improved conduction through solids.

Most TIMs are polymer-based composites. These are loaded with filler particles that are thermally conductive. The common fillers are aluminum oxide, boron nitride, aluminum nitride and magnesium oxide. If galvanic isolation is not required, metal fillers such as silver can also be used.

A certain amount of pressure between the interfaces is required to reduce the contact resistance. This pressure then compresses the filler particles and allows the material to flow into the surface irregularities. Once the material is in place, the effective thermal resistance of a TIM includes the volume resistance of the material and the contact resistance between the TIM and its cut surfaces.

Application problems for thermal interface materials

Although thermal interfaces and TIMs are typically already considered in the design process, some special factors should be considered when actually selecting the thermal interface material:

- The most important specification is definitely the thermal impedance, which is measured in degrees K in2 / W. This is an application-specific measure for the ratio of the temperature difference between two mating surfaces to the stationary heat flow through these surfaces. Due to the additional mounting pressure and the size of the area, the thermal impedance typically decreases while increasing with the thickness of the TIM.

- The ability of a material to conduct heat regardless of its thickness is referred to as thermal conductivity and is measured in W / mK. TIMs can be compared with the values of the thermal conductivity, but this value does not say anything about how good the ability of the material is to minimize the contact resistance.

- The distance (gap) between the heat source and the heat distributor is also important. Normally, the thinner the TIM, the better. However, the interfaces are never perfect, so a minimal material thickness is required to compensate for the irregularities.

- The surface flatness of the cut surfaces is a decisive factor in selecting the type of material. Are e.g. both surfaces flat, grease and thin films are a particularly good option - but this is rarely the case. Plastic ICs are usually concave in the middle. If the heat sink is very flat, the contact area is reduced, especially at the edge. This leaves an air pocket in the middle.

- Sometimes electrical insulation, measured in kV, is necessary. TIMs that have a silicone base share this property with thicker materials such as gap fillers. Thinner phase change materials and grease, however, are not necessarily reliable electrical insulators. For its part, graphite is electrically conductive.

- If you work with irregular surfaces, compressibility is a decisive factor. A good example is if you want to cover a whole range of components. For example, if heat and excess pressure are exerted on a silicone-based TIM, silicone can escape and migrate along the circuit board. If the pressure is insufficient, there is excessive thermal resistance at the interface.

- The temperature range in which the material can be used is also important. For example, silicone-based TIMs can be exposed to higher temperatures than silicone-free options.

- The UL flame class rating is required for most TIM applications. The majority of the materials up for selection are available with V-0 values that meet the typical requirements.

- Normally, silicone is an excellent thermal material with a high temperature range. Nevertheless, there are areas in which silicone-free variants have to be used. For example, the use of silicone in space is not possible due to outgassing.

- One should also pay attention to a simple application. After all, the type of fastening is a clear cost and performance decision. For example, small heat sinks are usually simply attached with double-sided thermal tape, while larger heat sinks require additional mounting parts. Adhesives can be applied to both or one side of the thermal material as needed. It should be noted here that the thermal impedance is increased with each layer of adhesive.

- You should also ask yourself how easy it is to handle the selected materials in a manufacturing environment. Can the materials be easily reworked, e.g. if the heat sink needs to be removed? Phase change materials and grease must be completely replaced, while some gap fillers can be reused.

- And finally, the long-term stability of the material should also be considered. This depends on factors such as usage temperature, time, application, and material properties.

Thermal interface material options

Phase Change Materials

The special thing about phase change materials (PCMs) is, that using heat from the operating processor and light clamping pressure they go through a transition - from a solid to a semi-solid phase. The semi-solid phase has the property of adapting very easily to both surfaces. The ability to completely fill the interface air gaps and surface voids under slight clamping pressure enables this material to perform at a level equivalent to that of the thermal plate.

PCMs are much less fluid than grease. However, PCMs contain wax and the moment the melting temperature is reached, the PCMs can flow out of narrow areas. Fortunately, recently launched PCMs are no longer wax based and therefore do not drip.

PCMs are quite easy to use at normal room temperature because they are firm. This provides more control when applying the firm pads to the heat sink surface. Many phase change pads create a very stable adhesive connection between the heat sink and the processor. Therefore, one has to be careful when removing the heat sink from the processor. Usually a small twist or turn will help to remove. If you use too much force, the processor can be damaged.

Thermal greases

Thermal greases are usually silicone, which is enriched with heat-conducting fillers. Hardening is usually not necessary, and they can flow and adapt perfectly to the interfaces. The thermal interfaces can be easily reworked. However, it must be ensured that enough paste or grease has been applied before installing the heat sink. Too little grease can result in gaps between the heat sink and the processor. On the other hand, too much grease can also be counterproductive, as this can lead to air gaps and leaks outside the interface. It should also be noted that some greases can deteriorate or dry out over time. Of course, this has a negative effect on the heat transfer performance. Greases as interface materials (TIM) are nevertheless the first choice in applications with high-performance processors - despite the disadvantages mentioned above. This is mainly due to the fact that the thermal conductivity of thermal greases is in the order of 10 W / mK, which is clearly superior to other TIMs.

Gap filler

One of the largest market segments of the TIMs are gap fillers, which can be supplied in different strengths. These efficient, soft, and highly thermally conductive materials can cover gaps up to a quarter of an inch. The practical gap fillers can cover several components of different heights and then transfer the heat to a common heat distributor. These pads are often used when low compression forces are required. The relatively high compressibility is therefore an important feature of this type of TIM. The gap fillers can also be individually shaped and the new form-in-place gap filler compounds in particular are a popular option for the automation of large volumes.

Thermal films

Thermal films or foils not only do the heat transfer, they also provide electrical insulation. When it comes to tearing and cutting irregularities on the heat sinks, the thermal foils offer excellent durability. This category includes silicone, silicone-free (e.g. polyurethane filled with ceramic) and graphite materials. The range of heat conducting performance and price ranges is wide, so that everyone can find a good solution.

Thermal pads

Thermal pads generally consist of molding unreinforced silicone with conductive fillers. The reinforcements for thermal pads are typically woven glass, metal foils or polymer films. The practical thermal pads are usually pre-cut in different sizes to accommodate components of different sizes. As far as the conduction is concerned, phase change materials and thermal paste are clearly superior, but the thermal pads have the advantage that they are an inexpensive and convenient option for applications with less cooling requirements.

Graphite foils

This inexpensive option has been used for a long time. The foils are electrically conductive and can be used well at extremely high temperatures up to 500 °C. Some providers align the fibers horizontally. This results in vastly different thermal conductivity measurements. For example, you can find on the x-axis with 7.0 W / mK and on the y-z axis with 150.0 W / mK - a clear difference.

Double-sided adhesive tapes

A thermal adhesive tape consists of an intricately woven, nickel-coated copper net that adapts closely to irregular mounting surfaces. For the attachment of small heat sinks to components, heat-conducting double-sided adhesive tapes made of PSA are very often used. Important factors here are the peel strength, the overlap and punch shear strength, the holding force, and the thermal resistance. As far as the performance in terms of heat conduction of the double-sided adhesive tapes is concerned, this is in the middle range. Additional assembly parts are saved, but the belts have problems with irregular surfaces of the components and can therefore only be used to a limited extent. Plastic ICs are typically concave in the middle and the heat sink surfaces also vary, which can cause air gaps in the interface.

Thermal adhesives

Thermal adhesives can be both one and two component systems. These are equipped with conductive fillers. It is usually applied by dosing or stencil printing. A hardening of the adhesive is necessary in order to enable a safe cross-linking of the polymer, which offers the adhesive property. The fact that the thermal adhesives offer structural support and that therefore no mechanical clamping is necessary, is certainly the greatest advantage of this TIM.

Thermal gels

Gels are a similar material to grease, which is slightly cross-linked. The behavior is similar, whereby the pumping of the material is reduced.

Metal TIMs

Interfaces made of metal can be produced in all possible forms and are currently no longer limited to use with soldering. The TIMs made of metal are quite easy to rework in numerous applications and can also be easily recycled.

Recently, the need for powerful TIMs in special devices, such as power amplifiers and IGBT modules have risen, which has prompted manufacturers to explore other types of metal TIMs. Good examples are liquid metals, phase change metals and SMA-TIMs (soft metal alloys).

The easiest to use is certainly the soft or compressible thermal metal interface material (SMA-TIM). Metal TIMs are very thermally conductive, reliable, and easy to use with compressible metals.

Recently, a hybrid material has also been developed, which consists of a heat-conducting silicone film on one side and a copper film on the other side. This material is particularly suitable for the production of flexible circuits and for protection against EMI and RFI noise.

Conclusions

Unfortunately, thermal interfaces are often considered rather late in the design phase of cooling systems. This is definitely not the best course of action. After all, the TIMs are clearly a decisive factor for the cost of heat management designs. Nowadays, more and more excess heat is typically to be managed, which is why there is clearly a high demand for high-performance TIMs.

With thoughtful use, thermal interface materials are sure to help reduce the size of heat sinks and the need for larger and larger fans. In addition, a good TIM is a simpler, faster, and clearly cheaper option than changing the heat sink or completely redesigning the housing.

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