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What is a Thermal Interface?

This application note is an introduction to the mechanics of a thermal interface. A thermal interface is an area where heat flows between two objects. There are many solutions to the obstacle of cooling an area of heat generation, and these are further discussed in the Thermal Interface Materials (TIM) application note. It is important to first step back and consider the overall thermal interface.

Q – Heat Transfer

By adjusting the variables of the equation for conduction heat transfer, it is possible to optimize the amount of heat transferred. The equation is shown below:

$$\frac{Q}{t} = \frac{kA(T_h - T_c)}{d}$$

Where:

Q = heat transferred (watts)
t = time
k = thermal conductivity of material [W/(cm·°C) or W/(m·K)]
A = contact area (cm^2 or m^2)
T_h = temperature of hot surface
T_c = temperature of cold surface (°C or K)
d = thickness of thermal interface material (cm or m)

A different description of the interface is the form of thermal resistance, which is denoted as:

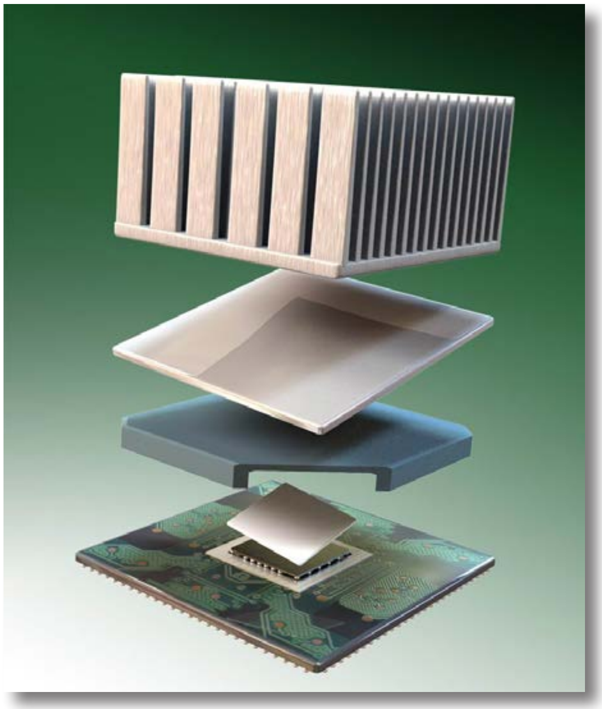
$$R = d/k \; (°C \cdot cm^2/W)$$

where $R = R_{interface1} + R_{bulk} + R_{interface2}$

In this form, the thermal resistance of a series of interfaces are additive. Typically, the thermal interface between the semiconductor device and the heat-sink is separated into three components: the device interface, the conductive material, and the heat-sink interface.

k – Thermal Conductivity of Material

One of the most important characteristics of a good thermal interface material is thermal conductivity. Thermal conductivity is commonly measured in either W/(cm·°C) or W/(m·K). This property will dictate how efficiently the thermal energy will flow though the material. Thermal conductivity is listed as a constant at a set temperature, and generally changes little between 300 - 500 degrees Kelvin. Heat is transmitted much better at near-cryogenic temperatures and is generally slower as temperatures increase.



Thermal cycle behavior is also important. The material that is used to transfer heat must be able to withstand the environment in which it will be placed. It must also be soft enough to endure mismatches in thermal expansion rates between the materials to which it will bond. A brittle material may crumble, whereas a liquid material may be pushed out of the interface area.

If the material has empty spaces or voids, it cannot transfer heat as well. It is important to minimize voiding because air pockets actually insulate the heat instead of conducting it. Voids can be caused by a phenomenon where the TIM is pushed out of the interface area. This is called "pump out."

OVER→

APPLICATION NOTE

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A – Contact Area

The contact area can be increased by choosing a material that will either conform to or wet to each surface. Thermal interface materials are more effective if they are able to fill in the surface irregularities that would otherwise become small air pockets. Some materials are sold with only this criterion in mind and, although they have relatively low thermal conductivity, they are still useful to eliminate air gaps between the heat generator and heat recipient. It is important to note that the heat transfer between material boundaries can become even more important than the heat transfer through the interface material itself.

d – Thickness of Thermal Interface

Decreasing the thickness of an interface also improves thermal transfer. The distance that the thermal interface material occupies is known as the bond line thickness. Typical bond-line thicknesses range from .001 to .005 inches. As the thickness of the bond-line decreases, the distance that the heat energy has to travel also decreases.

TIM Categories

In semiconductor applications, thermal interface materials are grouped by the parts of the assembly to which they interface.

- TIM 1 refers to an interface at the chip level between the chip and the heat spreader or thermal lid.
- TIM 2 designates the interface between the heat spreader or thermal lid and heat sink.

There are also emerging applications that require specialized heat dissipation setups. These new thermal situations do not fall into either the TIM 1 or TIM 2 categories.

Table of Applications

Application	STIM Solution
Semiconductor IC	In/In alloy
Power Semi	High-Pb Solder
LED/Photonics	AuSn
Power RF	AuSn

Conclusions

With new high power semiconductor devices being produced daily, there are many opportunities that challenge existing thermal interface solutions. Different solutions provide optimal integral mechanical attachment, large gap compliance, geometric and thermal stability, and heat transfer. Perhaps the best approach in the future is to design for heat transfer in tandem with other advanced packaging considerations. Integrating the interface design into the assembly is the proven route to successful thermal management.

APPLICATION NOTE