Understanding Thermal Performance Data:
Improve your ability to recommend the right thermal interface material

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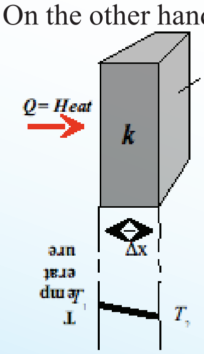
In the world of thermal interface materials there is a dizzying array of product offerings making various performance claims, based on an even more confusing list of test methods, protocols and reporting standards. This white paper seeks to bring order to the confusion by highlighting the importance of key thermal parameters and discussing why a sole focus on thermal conductivity can lead to an inappropriate material recommendation.

Thermal Conductivity vs. Thermal Resistance:

It is important to understand the relationship between these two often-quoted quantitative measures of thermal performance:

Thermal conductivity or bulk thermal conductivity refers to the intrinsic ability of any material to transfer heat through itself. For a heat transfer compound, bulk thermal conductivity depends on the amount and thermal conductivity of the fillers, as well as the shape, size and distribution of those fillers in the matrix.

On the other hand, many thermal engineers talk in terms of

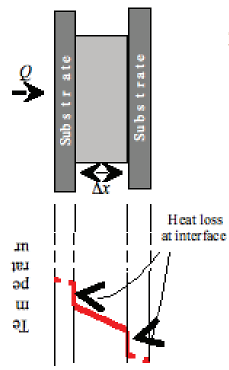


$$\dot{Q} = k\frac{\Delta T}{\Delta x}A$$

Thermal Conductivity (k) is Intrinsic Property of Material

thermal resistance, which describes the <u>opposition</u> to heat transfer in an assembly. This usually includes resistance to heat transfer across one or more interfaces as heat must transfer through one material, across an interface and through another material.

Thermal resistance is a function of bond line thickness (x),



Resistance to Heat Transfer in an Assembly

$$R = \frac{A}{Q}\Delta T = \frac{\Delta x}{k}$$

$$R_{Total} = R_{Interface\ 1} + R_{Bulk} + R_{Interface\ 2}$$

surface roughness and hardness of the two materials forming the interface. The resistance at the interface is sometimes referred to as *contact resistance*. Thermal resistance can be minimized by reducing bond line thickness, reducing surface roughness or increasing the bulk thermal property of the interface material.

Note that bulk thermal conductivity is only part of the overall thermal resistance calculation and refers only to transferring heat through the "bulk" of the material. It does <u>not</u> include or account for heat transfer across interfaces.

Methods for Testing Thermal Resistance and Thermal Conductivity:

There are many ways to measure thermal properties. Most methods can be categorized as either *transient* or *steady-state:*

<u>Transient method</u> introduces a pulse of heat, and thermocouples measure how well the heat dissipates from the system. Examples of equipment used to make this measurement are the Mathis Hotdisk and the Laser Flash.

<u>Steady-state method</u>, such as the common guarded hotplate method, applies a constant known heat source to one side of a plate, upon which rests the material to be tested, followed by another plate. Thermocouples are placed along both

plates, and testing is conducted under a constant pressure. Thermal resistance is calculated from temperature differentials collected from multiple thermocouples on each axis, and by the input power.

Reported thermal properties vary widely, depending on the specific test methods employed, temperature, pressure, substrate roughness, planarity, and thickness of test sample. Thermal conductivity should not be compared across various test methods or from vendor to vendor on data sheets, nor should thermal conductivity be the sole parameter upon which specification decisions are made.

To prove the point, the table below shows the difference between vendor-supplied thermal data and Dow Corning test results for exactly the same materials.

Application Dictates the Driving Thermal Performance Measure

	Thermal Conductivity Listed by Supplier (W/mK)	Measured Apparent Thermal Conductivity (W/mK)
Supplier 1		
Shore A Materials	3.5	2.5
	2.0	0.6
Shore 00 Materials	0.9	0.2
	2.0	1.3
	1.5	0.9
	1.0	0.7
Supplier 2		
Shore A Materials	2.7	0.8
	1.6	0.6
	1.4	0.9
	1.0	0.5
Supplier 3		
Shore 00 Materials	8.5	3.7
	6.0	1.5
Supplier 4		
Shore A Material	1.2	0.6
Shore 00 Material	1.5	1.4

Look to the bond line to determine which thermal property is most important in **selecting a thermal material**:

Applications requiring thin bond lines, **less than 50 microns**, should focus on thermal resistance measurements. To understand this, follow the heat transfer path. The heat will spend more of its time crossing the various interfaces than it will traveling through the "bulk" of the material. In technical terms, the resistance to heat flow across the interfaces is much larger than the resistance to heat flow through the thermal interface material itself. Therefore, thin bond line applications will be more affected by thermal resistance.

For thick bond line applications, **greater than 150 microns**, the situation is reversed. Again following the heat path, most of the resistance to heat transfer will come from traveling the length of the bond line through the thermal interface material. This resistance is typically larger than the interfacial or contact resistance. Since most of the resistance is coming from transferring heat across the thermal interface material itself, the higher the bulk thermal properties, the better.

What about bond lines **between 50 and 150 microns**? These applications require an optimized thermal interface along with good bulk thermal properties. In these cases, the dominant thermal parameter cannot be easily determined by simply looking at the bond line. There are a number of other material and application characteristics that affect the thermal performance. These characteristics are discussed in the follow-up paper, *"Understanding non-thermal property impact on thermal performance:* Improve your ability to recommend the right thermal interface material."

Summary

Thermal resistance and bulk thermal conductivity are the two most common ways to characterize the thermal performance of an interface material. Experience has demonstrated that selecting the material with the highest bulk thermal conductivity may not lead to the optimum material selection. The application bond line gives design engineers a clue as to which property is more influential. Typically, thermal resistance is the critical feature for thin bond lines -- less than 50 microns -- and bulk thermal conductivity is most critical for bond lines greater than 150 microns. Other material properties can also influence the thermal performance of a material and are discussed in the follow-up paper, *"Understanding non-thermal property impact on thermal performance:* Improve your ability to recommend the right thermal interface material."

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