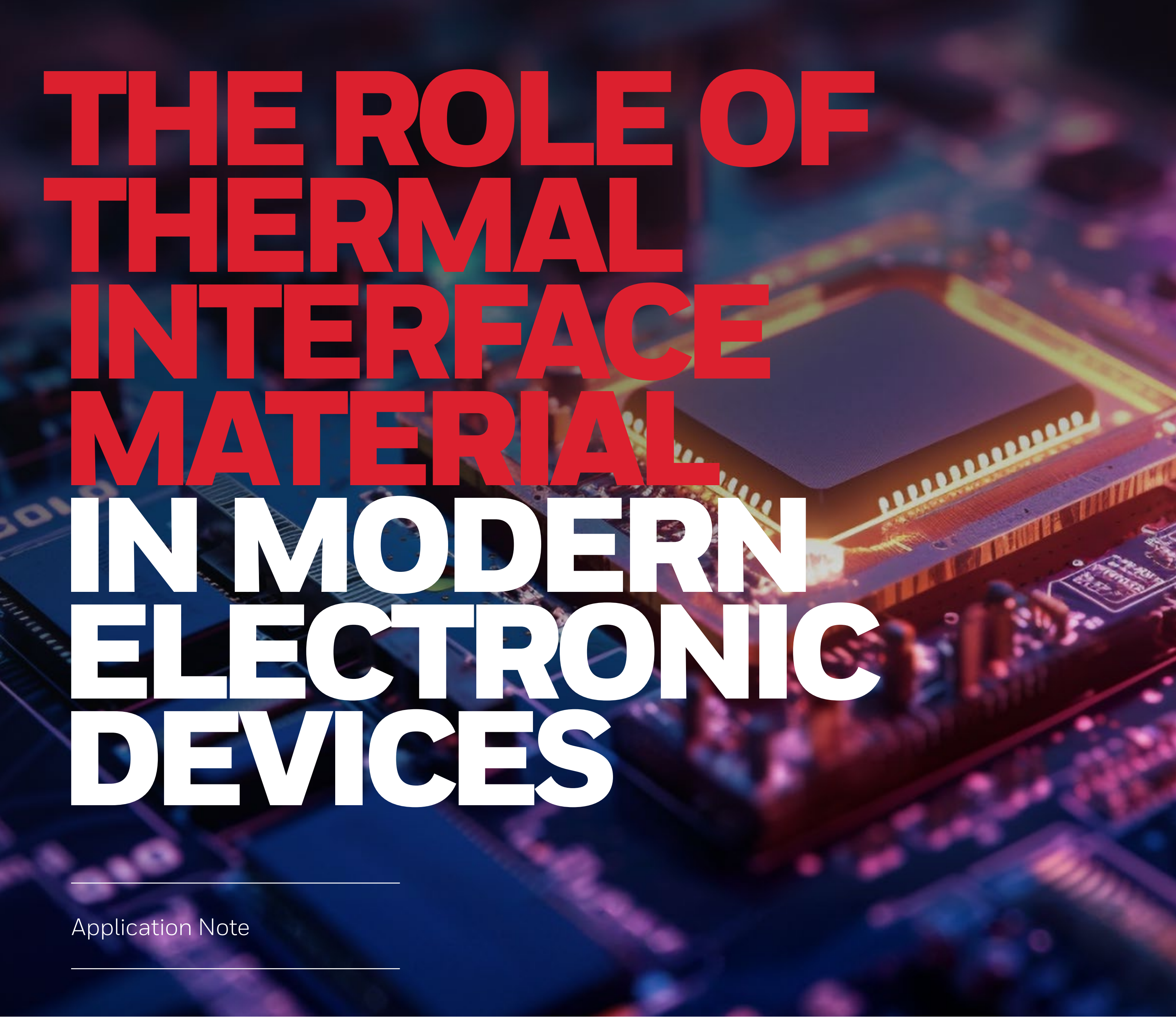


THE ROLE OF THERMAL INTERFACE MATERIAL IN MODERN ELECTRONIC DEVICES

Application Note

Thermal interface materials (TIM) play a critical role in the thermal management of electronic devices that are increasingly compact and powerful, and which often generate high levels of heat.

With the continuing trend of reduction of electronic device dimensions, there is a growing demand for effective cooling solutions as the electronics required to be more powerful and compact, and the increased data transfer speed and processing of 5G devices will generate elevated levels of heat. In this application note, we'll examine the applications driving TIM requirements, different types of TIMs, their composition, and key considerations when selecting such material.

Honeywell has met the advanced materials and application requirements of electronic device manufacturers for more than 50 years, and provides vital materials for thermal management across multiple industries.

INTRODUCTION

What is TIM, and why is it important?

> **TIM is a substance inserted between two components – typically a heat-generating device and a heat sink – to improve thermal conductivity and heat transfer. In electronic devices or systems, there are often air gaps or voids between interfacing components due to surface roughness, manufacturing imperfections, or misalignment during assembly. Air gaps can manifest as low thermal conductivity compared to most solid materials. As such, air gaps in electronic assemblies can increase thermal resistance and poor heat dissipation, causing localized hotspots, overheating, or potential device failure.**

Modern electronics are increasingly advanced in functionality and compact in footprint. More components in a limited space mean more power and more heat. Thermal management is essential for device reliability and performance, but implementing it effectively can be a challenge. TIM acts as a critical thermal path; it is designed to dissipate heat from the device to the spreader or heat sink by filling air gaps and improving thermal contact between interfacing surfaces (See Figure 1). The result is effective cooling for devices.

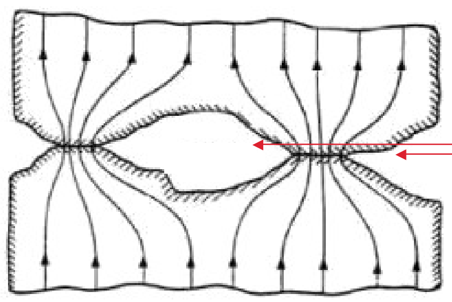


Figure 1. Constriction of heat flow contacting rough surfaces.

WHAT APPLICATIONS ARE DRIVING TIM REQUIREMENTS?

There are three segments in two markets for TIM based on the most common application and point of use. TIM 1 is used in semiconductor packaging, where it is typically installed between the top of a bare flip chip die and an applied flip chip lid. Meanwhile, TIM 1.5 and TIM 2 are often used in PCB and systems assembly. In this context, TIM 1.5 is installed between the top of a bare flip chip die and a heat spreader, heat sink, or heat pipe for a no-lid design. In contrast, TIM 2 is installed between a packaged semiconductor and a heat sink or between a module and a secondary heat sink or heat spreader. Figure 2 shows the schematic of thermal interface materials in both markets.

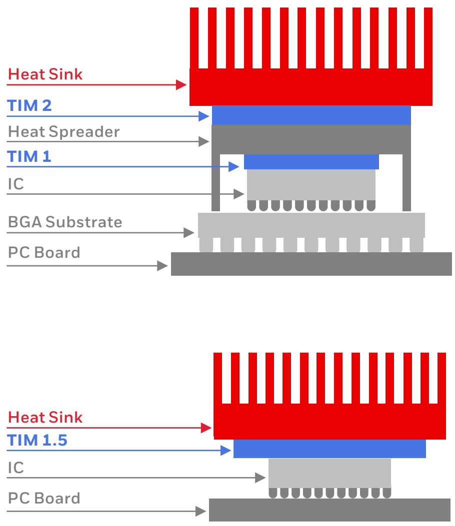


Figure 2. A: Schematic of thermal interface materials used in a flip-chip package. TIM 1 is placed between the chip (or die) and the integrated heat spreader. TIM 2 is placed between the IHS and the heat sink; B: TIM 1.5 is placed between the chip and the heat sink.

WHAT TYPES OF TIM ARE AVAILABLE?

TIMs can be segregated in many ways. They are often separated by material, whether introduced in a solid or liquid form. An overarching split is if the interface material is introduced in a solid or liquid form. There are significant overlaps, but some unifying differences between these two forms are outlined below.

Liquid:

- **Thermal grease/paste:** Original, non-fabricated TIM is frequently used for high-end applications due to its superior thermal performance and low-end applications due to its potential low cost.
- **Gel:** Non-fabricated TIM is applied like a grease but cured-in-place or precured to yield a loosely cross-linked material with a low modulus. Considered a type of grease.
- **Liquid adhesive:** Thermal adhesives provide mechanical attachment between a heat-generating part and a heat sink after a cure step.
- **Liquid gap filler:** Dispensable material that can be pre-polymerized or supplied as a two-part solution that cures; designed to displace gap filler pads.

Solid:

- **Phase change:** This is an easy-to-apply replacement for thermal grease that is solid at room temperature but softens and becomes a liquid at the device's operating temperature.
- **Gap filler pads:** These are thick, compliant sheet materials used to fill large gaps between heat-generating components and a heat sink.
- **Tape adhesives:** Thermally conductive pressure-sensitive adhesive (PSA) tape provides mechanical attachment between heat-generating components and a heat sink.
- **Films:** Thermal material provides electrical insulation between a heat-generating component (i.e., a power semiconductor) and a heat sink.

WHAT ARE THE KEY CONSIDERATIONS WHEN SELECTING TIMS?

Selecting a TIM for an electronic device requires consideration of the application requirements and potentially some trade-offs. Here are some critical criteria:

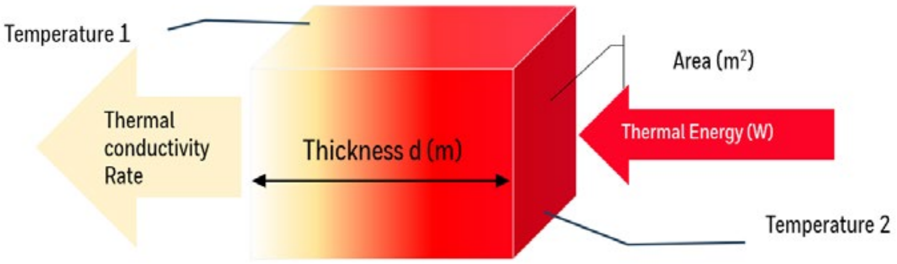
- **Overall thermal performance:** TIMs' primary function is to enhance heat transfer between components. To ensure efficient heat dissipation, it is recommended to choose a TIM with high thermal conductivity and lower thermal resistance. Typical values range from 1-10W/mK or higher for high-performance applications.
- **Operating temperature range:** TIMs need to function effectively within the temperature range of the application.
- **Material characteristics:** TIMs must maintain their integrity and performance under mechanical stress in some applications. Properties such as hardness, compressibility, and flexibility should be evaluated. In other applications, electrical insulation is necessary. You may want to avoid electrically conductive TIM for applications that require electrical insulation.
- **Reliability and longevity:** TIMs should maintain their performance over a device's lifespan. You should consider a material's long-term stability, thermal cycling resistance, and potential long-term degradation.
- **Processing and manufacturing characteristics:** Think about the impact on processing and manufacturing processes on TIMs to ensure seamless production fit. Consider compatibility with automated processes, ease of integration into assembly lines, rework ability, and quality control requirements etc.
- **Cost:** Cost-effectiveness is critical for large-scale manufacturing. For target applications, try to balance performance with cost.
- **Environmental and safety:** Choose non-toxic and non-flammable materials to ensure TIMs comply with environmental regulations and safety standards.

WHAT ROLE DOES THERMAL CONDUCTIVITY PLAY IN TIMs?

A material's ability to conduct heat is called thermal conductivity. It is an intrinsic property of material, independent of shape or size. When it comes to thermal management, materials that deliver high thermal conductivity are ideal[1].

$$K = \frac{Qd}{A\Delta T}$$

Where:
K = thermal conductivity;
Q = amount of heat transferred;
d = distance between the two isothermal planes;
A = area of surface;
ΔT = difference in temperatur.



THERMAL IMPEDANCE

Thermal impedance is a measure of the sum of:

- thermal resistance;
- thermal contact resistance of a material.

Thermal resistance is a thickness-dependent property and can be calculated by:

$$R_0 = \frac{L}{kA}$$

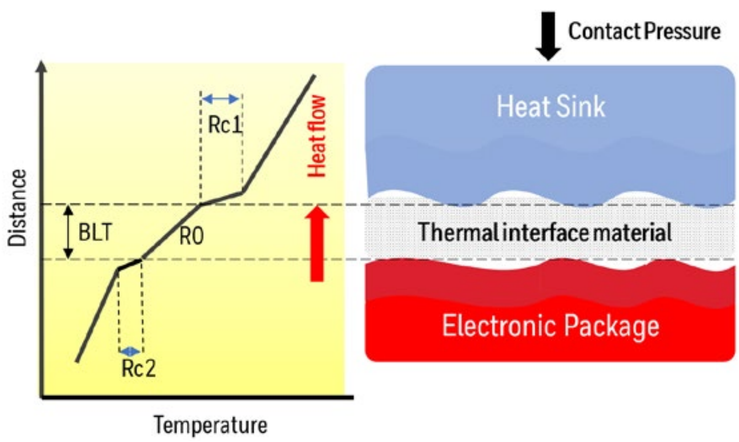
Where:
k = thermal conductivity [W/mK];
L = plane thickness [m];
A = plane area [m^2].

THE TOTAL THERMAL IMPEDANCE (R) IS GIVEN BY:

$$R = R_{C1} + R_0 + R_{C2}$$

Where:
R_{C1} and R_{C2} is the contact resistance between the upper surface and TIM and lower surface and TIM separately.

There are factors that could impact the overall thermal impedance. Thermal impedance is the total of all the combined thermal resistance and contact resistance values. Interface contact resistance is determined by material hardness, viscosity, the bond line thickness, and the surface wetting capability. Material thermal resistance can be determined by conductivity, thickness and contact area. When applying contact pressure, the TIM should be flexible enough to conform to the asperities of the mating surface while maintaining a small bond line thickness, low contact resistance and reasonably bulk thermal conductivity[2].



1. Thermal conductivity and resistivity - Wikipedia
2. Jens Due and Anthony J. Robinson, Reliability of thermal interface materials: A review, Applied Thermal Engineering, Volume 50, Issue 1, 2013, Pages 455-463.

WHAT TYPES OF TIM DOES HONEYWELL OFFER?

CHOOSE YOUR MARKET VERTICALS

VERTICALS	CONSUMER ELECTRONICS				TELECOM / DATA CENTER			AUTO ELECTRONICS / EV					POWER INDUSTRY
Sub-segment	Notebook/ Tablet/PC	Projector	Camera / GPS	Gaming console	Server	AI / HPC	Networks	Inverter	DC / DC Converter	On-Board Charger	ECU	ADAS	Solar Converter
Applications	GPU / CPU	Laser	CPU / Memory	GPU / CPU	GPU / CPU / Memory	GPU / CPU	Base Station / Optical Tranceiver / Switch	IGBT Module	Power Module	Power Module	Lighting device / Others	GPU / CPU/ Memory/ Power Device	IGBT Module
Products Offering	PTM7950 PTM7950SP /PTM7900 PTM7900-SP /HLT3500	PTM7900 PTM7950-SP	TGP3500PT TGP6000PT HLT3500	PTM3180	PTM7900 TGP3500PT TGP6000PT TGP8000PT	PTM6000 PTM7900 PTM7950 PTM6880	PTM7950 PTM7900 PTM7000 PCM45F RTM-X22	PTM7000 PTM7000-SPM / Grease	TG5500 TIP5000 TIP3500	PTM6000-SPM PTM7000 - SPM	TG3010I HT7000 HLT2000	PTM7000 PTM7900/ HLT7000 HLT8000 HLT10000 HT1000	LTM6300-SP PTM6000HV-SP

CHOOSE YOUR PHASE CHANGE MATERIAL

	Specific Gravity (g/cm³)	Viscosity (Pa·s)	Thermal Conductivity (W/mK)	Thermal Impedance @ no shim (°C cm²/w)	Volume Resistivity (Ω·m)	Phase Change Temperature (˚C)	Operating Temperature Range (˚C)	Typical Bondline Thickness @30psi/ 60° C (mm)	Minimum Bondline Thickness for Best Performance (mm)	Format	Appearance	Liner Color	Supplied Thickness (mm)	Extend Drying Type	Fast Drying Type
	ASTM D374	**Rheometer HON**	**ASTM D5470**	**ASTM D5470 Modified**	**ASTM D257-700**			**HON**	**HON**						
LTM 6300-SP	1.8	150	2.0	0.4	$3x10^{15}$	45°	-55° - 120°	0.025	0.038	Paste / Printable	Grey	N/A	N/A		X
PCM45F	2.2	N/A	2.4	0.09 - 0.12	$2.1x10^{14}$	45°	-55° - 150°	0.025	0.038	Pad	Grey	Pink	0.2 / 0.25 / 0.3 / 0.4 / 0.5		
PCM45F-SP	1.7	100	2.4	0.09 - 0.12	$2.1x10^{14}$	45°	-55° - 150°	0.025	0.038	Paste / Printable	Grey	N/A	N/A		X
PCM45F-SPM	1.7	100	2.4	0.09 - 0.12	$2.1x10^{14}$	45°	-55° - 150°	0.025	0.038	Paste / Printable	Grey	N/A	N/A	X	
PTM5000	2.3	N/A	4.4	0.06 - 0.08	$2.1x10^{14}$	45°	-55° - 150°	0.025	0.038	Pad	Grey	Pink	0.2 / 0.25 / 0.3 / 0.4 / 0.5		
PTM5000-SP	2	82	4.4	0.06 - 0.08	$2.1x10^{14}$	45°	-55° - 150°	0.025	0.038	Paste/ Printable	Grey	N/A	N/A		X
PTM5000-SPM	2	82	4.4	0.06 - 0.08	$2.1x10^{14}$	45°	-55° - 150°	0.025	0.038	Paste / Printable	Grey	N/A	N/A	X	
PTM6000	2.3	N/A	4.4	0.06 - 0.08	$2.1x10^{14}$	45°	-55° - 150°	0.025	0.038	Pad	Grey	Yellow	0.2 / 0.25 / 0.3 / 0.4 / 0.5		
PTM6000-SP	2	222	4.4	0.06 - 0.08	$2.1x10^{14}$	45°	-55° - 150°	0.025	0.038	Paste / Printable	Grey	N/A	N/A		X
PTM6000-SPM	2	222	4.4	0.06 - 0.08	$2.1x10^{14}$	45°	-55° - 150°	0.025	0.038	Paste / Printable	Grey	N/A	N/A	X	
PTM6000HV-SP	2.6	200 - 460	5.2	0.08 - 0.10	$2.1x10^{14}$	45°	-55° - 150°	0.025	0.038	Paste / Printable	Grey	N/A	N/A	X	
PTM7000	2.7	N/A	6.5	0.04 - 0.07	$2.1x10^{14}$	45°	-55° - 150°	0.025	0.038	Pad	Grey	Light Blue	0.2 / 0.25 / 0.3 / 0.4 / 0.5		
PTM7000-SP	2.3	120	6.5	0.04 - 0.07	$2.1x10^{14}$	45°	-55° - 150°	0.025	0.038	Paste / Printable	Grey	N/A	N/A		X
PTM7000-SPM	2.3	120	6.5	0.04 - 0.07	$2.1x10^{14}$	45°	-55° - 150°	0.025	0.038	Paste / Printable	Grey	N/A	N/A	X	
PTM7900	2.8	N/A	8	0.04 - 0.08	$2.1x10^{14}$	45°	-55° - 150°	0.025	0.038	Pad	Grey	Light Blue	0.2 / 0.25 / 0.3 / 0.4 / 0.5		
PTM7900-SP	2.5	177	8	0.04 - 0.08	$2.1x10^{14}$	45°	-55° - 150°	0.025	0.038	Paste / Printable	Grey	N/A	N/A		X
PTM7950	2.8	N/A	8.5	0.04 - 0.08	$2.1x10^{14}$	45°	-55° - 150°	0.025	0.038	Pad	Grey	Light	0.2 / 0.25 / 0.3 / 0.4 / 0.5		
PTM7950-SP	2.5	100	8.5	0.04 - 0.08	$2.1x10^{14}$	45°	-55° - 150°	0.025	0.038	Paste / Printable	Grey	N/A	N/A		X

For more information

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