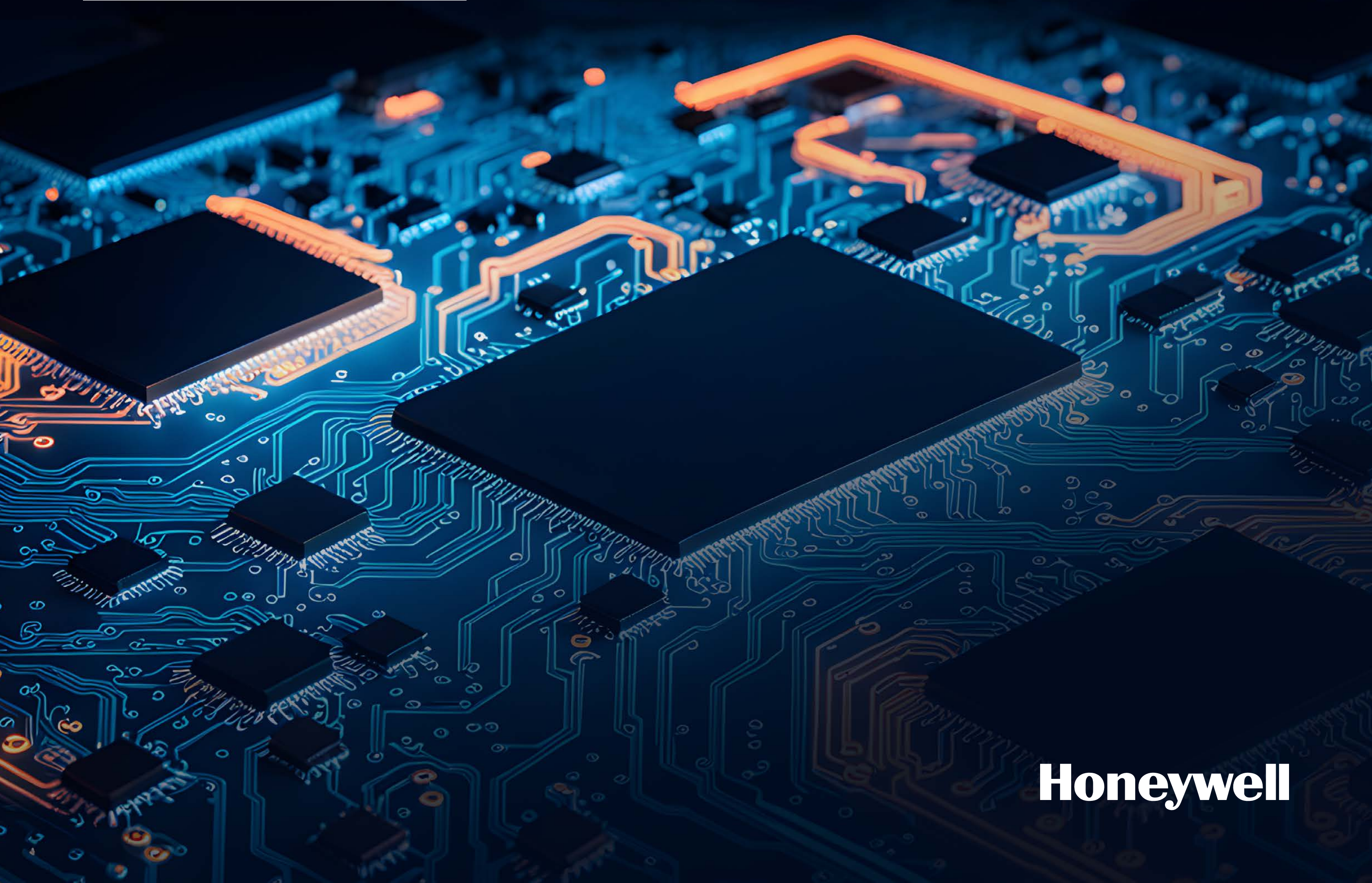
OPTIMIZING AI SYSTEMS: ENHANCING PERFORMANCE AND RELIABILITY WITH TIM 1.5 THERMAL SOLUTIONS

Application Note



Honeywell

INTRODUCTION

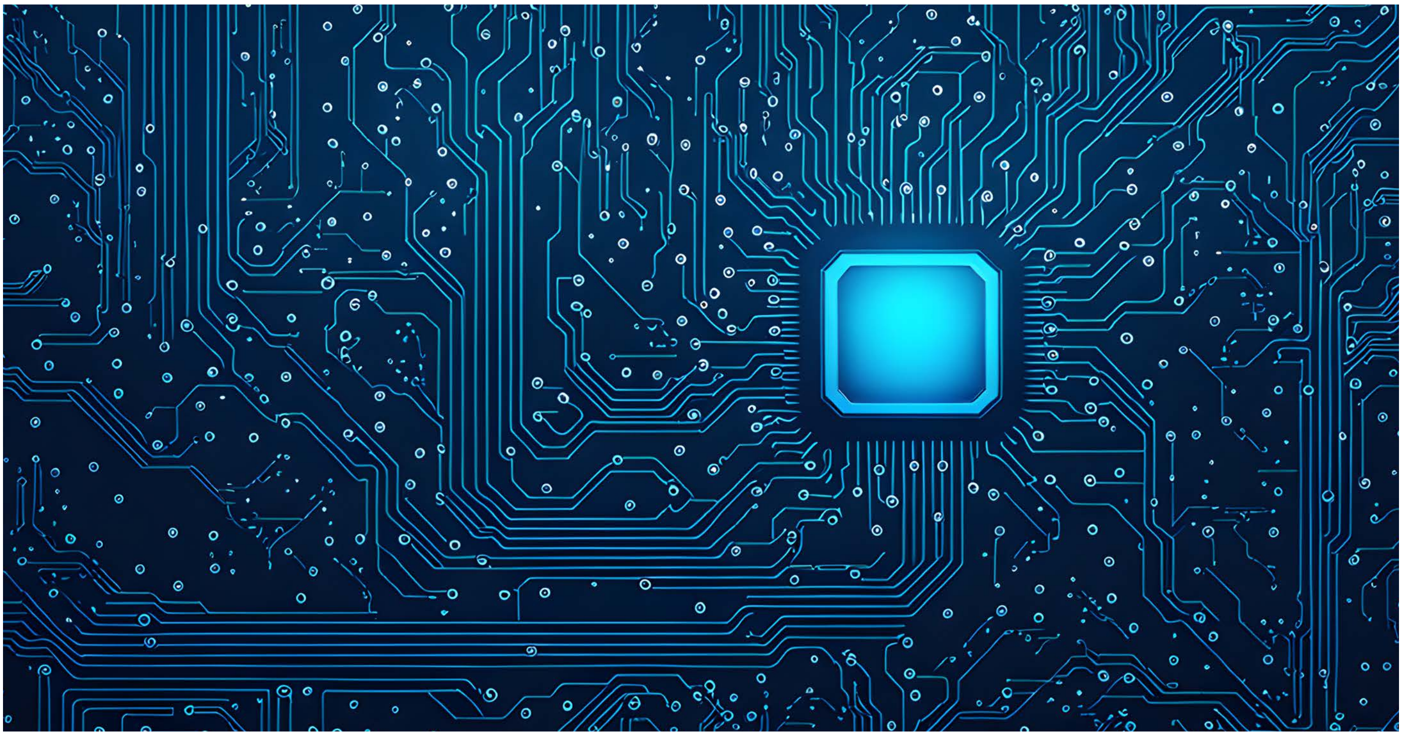
In the rapidly evolving field of artificial intelligence (AI), optimizing system performance and reliability is crucial for meeting the demands of complex computational workloads. As AI applications grow in complexity, the thermal management of high-performance processors is becoming more challenging. In this application note, we explore the role thermal interface material (TIM) 1.5 plays in the performance and reliability of AI systems. By effectively managing heat dissipation, TIM 1.5 ensures optimal operating temperature, reducing the risk of thermal-induced failure and extending system longevity. As an advanced materials supplier, Honeywell has met the application requirements of electronic device manufacturers for more than 50 years and continues to provide vital materials for thermal management across multiple industries.

The increasing application of artificial intelligence (AI) across sectors and industries is driving demand for thermal interface material (TIM) that support the technology's performance and reliability. One application of TIM – called TIM 1.5 – can improve the efficiency and longevity of AI systems by reducing the risk of thermal-induced failure. Let's explore the factors behind market demand for TIM and then examine the characteristics and benefits of TIM 1.5.

THE RISE OF AI

AI – including deep learning, machine learning and neural networks – refers to the simulation of human intelligence in machines designed to think and learn like humans. Such systems can make decisions, process plain language for customer engagement, translate languages and process visible light to obtain information. The impact of AI can be seen in applications such as autonomous driving and advanced driver-assistance systems in the automotive industry, diagnostics and imaging analysis in the healthcare industry, fraud detection and prevention and risk management in the finance sector; quality control and defect detection in manufacturing, network optimization and management in the telecommunications industry, and much more.

AI models are being trained with increasing complexity to keep pace with user expectations for the technology. This, coupled with the expanding volume of data, necessitates the greater computational power of their training. Graphics processing units (GPUs) enable parallel processing (i.e. the handling of multiple operations simultaneously) for efficient computation, the training of AI models, the quick and accurate processing of large volumes of data, and more.



TIM 1.5 AND ITS ADVANTAGES

Demand for high-performance computing is driving the development of TIM 1.5, which manages the heat generated by powerful AI processors and GPUs.

There are three segments in two markets for TIMs based on applications and points of use. TIM 1 is used in the semiconductor packaging process, where it is installed between the top of a bare flip chip die and the flip chip lid. Meanwhile, PCB and systems assembly often use TIM 1.5 and TIM 2. Typically, TIM 1.5 (die to heat sink) is installed between the top of a bare flip chip die and a heat spreader, heat sink, or heat pipe, while TIM 2 is installed between a semiconductor and a heat sink or between a module and a secondary heat sink or heat spreader. Figure 2 shows the TIM in both markets.

The market for TIM 1.5 is being driven by advancements in technology, the increasing complexity of electronic devices, and the need for efficient thermal management. Why is TIM 1.5 so effective? Applying TIM between the die and sink optimizes thermal conductivity and provides efficient heat dissipation since it reduces interface contact resistance by reducing stacking layers. When applying TIM onto IC chips, a key consideration is reducing the risk of contamination and keeping the chips away from scratches and pits. Particles between the chip and TIM can cause abrasions to the chip surface, leading to scratches and pits that degrade the material and limit its functionality. The debris can concentrate stress, making the chip more susceptible to mechanical failure under normal operating pressure. As TIM 1.5 is used between the chip and heat sink, it may experience thermally induced deformation, leading to changes in bond line thickness, loss of corner coverage, and increased interface thermal resistance – all of which can affect heat dissipation.

Honeywell's PTM series offers TIM 1.5 solutions for AI that address the particle issue and warpage-induced change in bond-line-thickness (BLT). Based on a robust polymer phase change material (PCM) structure, the proprietary Honeywell material exhibits effective wetting properties during typical operating temperature ranges, resulting in low surface contact resistance. The material provides superior reliability and maintains low thermal impedance, making it ideal for high-performance integrated circuits. Honeywell's PCM is designed to handle large bare die and demonstrates excellent thermal performance on current-generation GPUs.

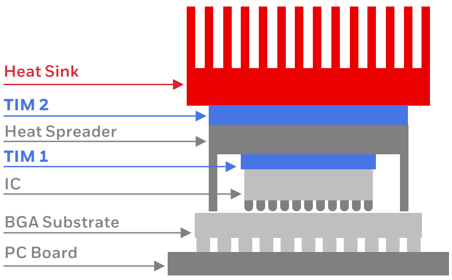


Figure 2A

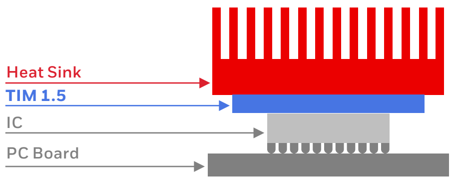


Figure 2B

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

As bond line thickness (BLT) directly impacts the thermal conductivity of the PCM, a thinner bond line improves heat transfer efficiency between the components it is sandwiched between. PCM transitions between solid and liquid phases to absorb and release heat, while a thinner BLT allows for more rapid and uniform phase transitions, which helps maintain consistent thermal management. Figure 3 shows typical Honeywell PCM BLT change over time when subject to different temperatures. With an initial thickness of 0.25mm (about 0.01 in) and diameter of 25.4mm (about 1 in), the PCM samples were heated from room temperature to 50°C, 65°C, and 80°C while maintaining a testing pressure of 30 Psi. The result demonstrates that the primary thickness change occurs in the first few minutes before reaching a plateau. It reaches its minimum BLT in less than 20 minutes. In contrast, a sample heated to a higher temperature will reach its minimum BLT earlier. During assembling and heating, electronic device materials expand under pressure. The PCM is expected to accommodate this expansion without cracking or losing contact with the surface. It is critical to optimize BLT to maintain mechanical integrity and thermal contact under various conditions and to ensure uniform distribution of contact pressure. The superior design of Honeywell's PCM optimizes the material's viscosity, affecting its ability to spread into a thin, uniform layer between surfaces in various applications.

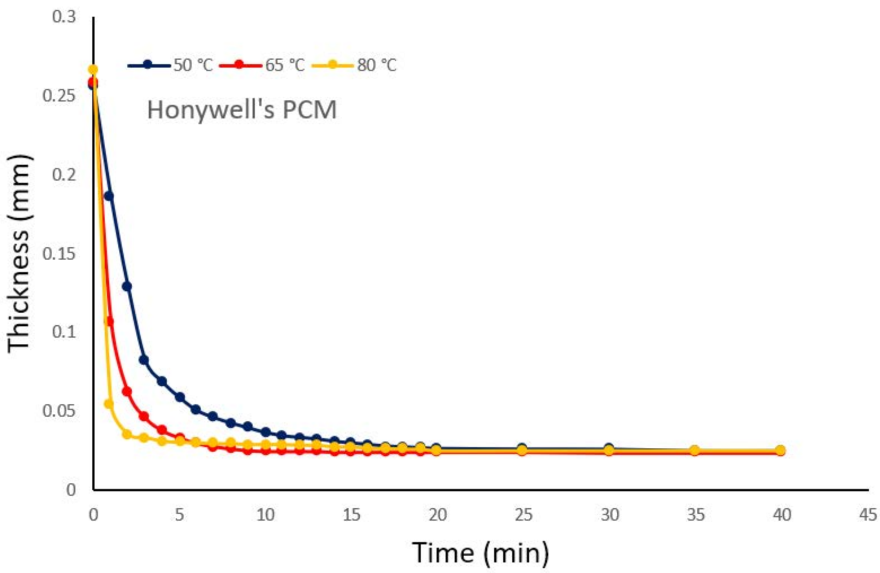


Figure 3. BLT changes as a function of heating time. Samples subjected to three temperatures.

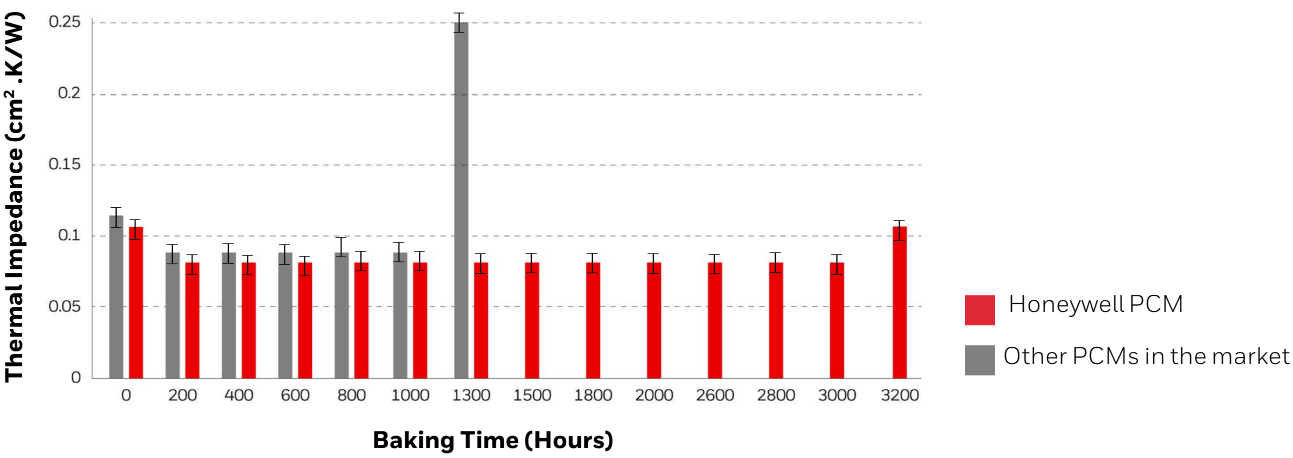


Figure 4. Comparison between typical PCM and Honeywell PCM for AI applications: high temperature baked at 150C over 3,000 hours. Thermal impedance (TI) properties comparison between typical PCM and Honeywell PCM for the AI industry. Test method: Laser Flash, ASTM E1461. Honeywell PCM delivers TI of less than 0.1 cm2.K/W and high thermal stability over time, providing excellent long-term wetting and reliability. TI of PCM slightly decreases after 200 hours due to improved wetting and remains stable thereafter.

HIGH THERMAL STABILITY (RELIABILITY) OVER TIME

A highly accelerated stress test (HAST) test between typical PCM and Honeywell PCM for AI applications was conducted at 130°C with a relative humidity of 85%. TI data was collected at 0 and 240 hours (Figure 5). The result shows no significant difference, indicating good reliability.

HIGHLY ACCELERATED STRESS TEST (HAST) (130°C 85% RH)

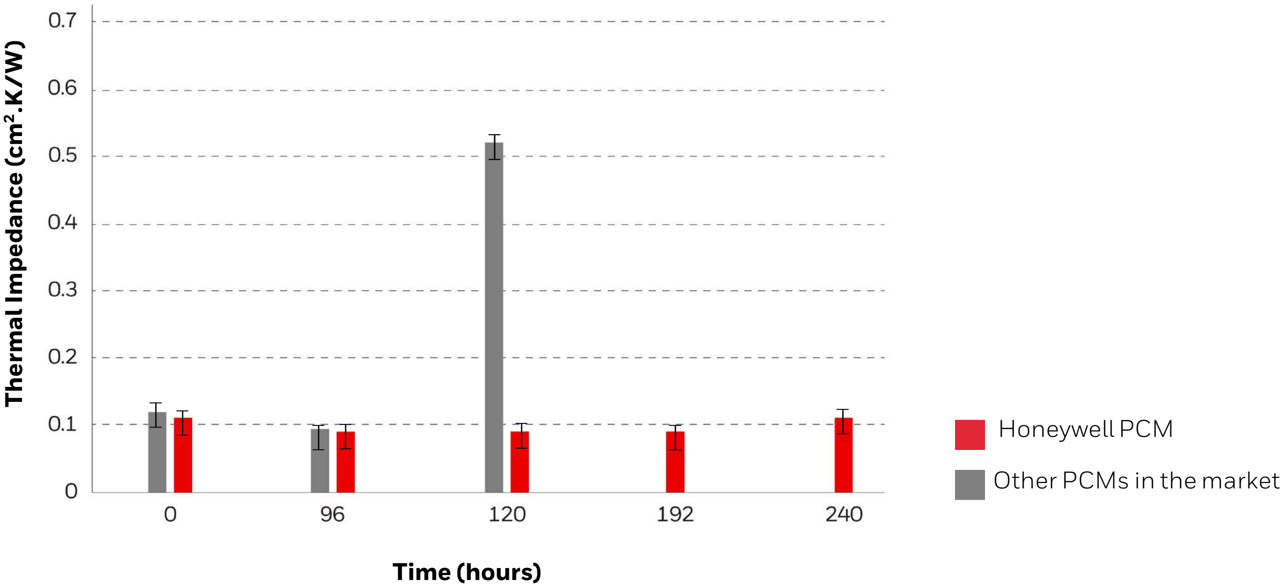


Figure 5. TI performance of PCM undergoing a highly accelerated stress test.

DRIPPING TEST

A TIM dripping test is conducted on a Honeywell PCM to evaluate its thermal stability and mechanical integrity under evaluated temperatures. It assesses whether the PCM can maintain its position and effectiveness without dripping or flowing out of place when subjected to high temperatures.

- The PCM pellet samples were prepared with a diameter of 15mm and thickness of 2mm and 3mm. Sample pellets were placed on ceramic and copper substrates and secured vertically to simulate conditions where gravity could cause dripping.
- The samples were placed in an oven at 90°C and 105°C, respectively. They were maintained at the target temperature and inspected every 15 minutes for signs of dripping, flowing, or displacement.
- After heating for one hour, a visual inspection was performed to check for dripping or flow marks. The displacement or loss of TIM was measured to quantify the amount of material that had dripped or moved.

Figure 6 shows the flow marks of the Honeywell PCM samples. The results show good adhesion under high-temperature applications, indicating low pump-out risk. The TIM remains in place without signs of dripping, sagging, or flowing away from the applied area at temperatures up to 105°C for the 2mm-thick samples. The bond line between the TIM and substrate remains intact and uniform.

No gaps, delamination, cracks, or separation were visible in the bond line for the 2mm and 3mm-thick samples. Honeywell TIMs can dissipate heat and prevent mechanical failure under high-temperature conditions by maintaining a stable bond line and consistent thickness and retaining physical and thermal properties. This significantly reduces the likelihood of thermal failure, contributing to the long-term reliability of electronic devices in the AI industry.

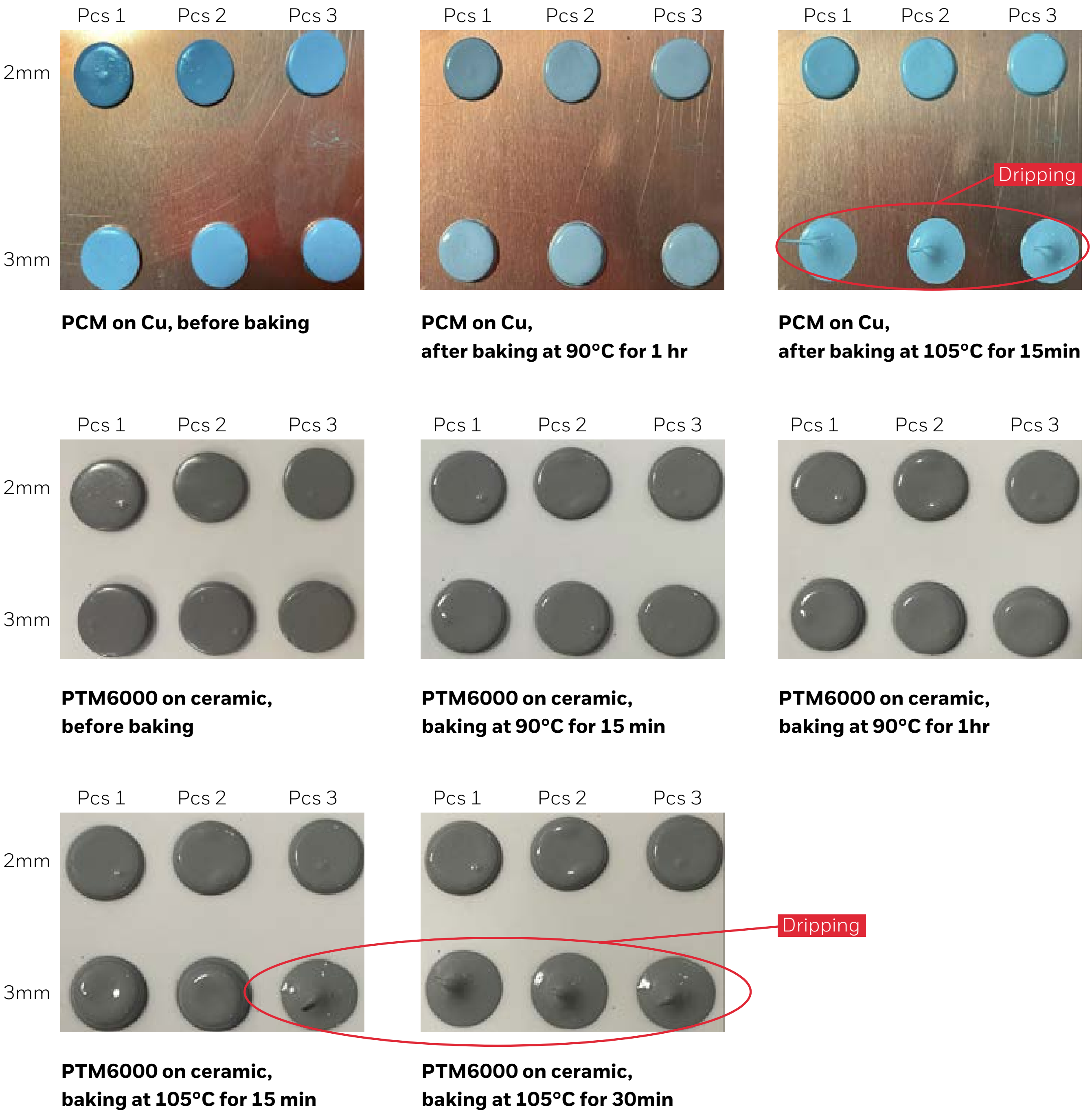


Figure 6. PCM sample dripping test performance.

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/cm^3)	Viscosity (Pa·s)	Thermal Conductivity (W/mK)	Thermal Impedance @ no shim $(^{0}C\ cm^2/w)$	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

SUMMARY

The market for TIM 1.5, which plays a critical role in the thermal management of a wide range of electronic and electrical systems, is expanding due to technological advancements, particularly the widespread adoption of AI. Honeywell's PTM series offers TIM 1.5 solutions that address industry concerns about particle contamination and warpage-induced change in bond-line thickness (BLT). Based on a robust polymer PCM structure, Honeywell's material exhibits effective wetting properties in typical operating temperature ranges, resulting in low surface contact resistance.

For more information

advancedmaterials.honeywell.com

Honeywell Advanced Materials

115 Tabor Road

Morris Plains, NJ 07950

advancedmaterials.honeywell.com

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