THERMAL MANAGEMENT SOLUTIONS FOR AUTOMOTIVE AND MIL/AERO

By: Joseph Forbes Petri, Electronics Assembly Solutions Account Manager, 3M

Presented by:
TTI, Inc.
2441 Northeast Parkway
Fort Worth, TX 76106-1896
www.ttiinc.com / 1.800.CALL.TTI

INTRODUCTION

IoT technology can be a two-edged sword. On the one hand as connectivity is integrated into all forms of smart devices, increased performance is a significant benefit, bringing cloud capabilities directly to the users and devices that need them. On the other, this increased performance together with an ever-shrinking PCB footprint results in the need to dissipate greater amounts of excess heat. This buildup of excess heat causes 55% of electronic systems to fail.

How can one avoid this trade-off? Enter Thermal Interface Materials (TIMs), a category of products used to aid thermal conduction between mated surfaces such as a semiconductor device and a heat sink. TIMs can increase a component's life span, reducing the temperature by 10ºC or more.

MARKET DRIVERS

Among trends that are driving the need for thermal interface solutions is data consumption. As devices get more powerful, to handle the amount of data being transferred over IP networks–megabytes, gigabytes even exabytes–results in generating more heat that must be managed through thermal interface solutions. Heat is an unavoidable byproduct that can be destructive if allowed to build unchecked. With the introduction of sub-10 nm semiconductor fabrication processes, current manufacturing trends have exacerbated the need for effective thermal management.

Another trend is connected devices. Look around inside your car at the number of connected devices within a new vehicle. Then there is the ever-growing use of circuit boards. Flexible printed circuit boards are going to drive the need for additional thermal interface solutions for lighting and display technologies for consumer electronics, as well as wearables with sensors that help monitor our health.

These trends in electronics are driving opportunities for thermal management. There are many solutions that can be used as an interface to enhance thermal coupling. These include thermal adhesives, thermal gap fillers (sometimes known as gap pads), thermally conductive tapes, thermal pastes, thermal greases, and thermally conductive epoxies. They all work toward moving heat to increase the performance and reliability of a device.

This white paper will cover how thermal interface materials work, review applications in automotive and aerospace, and examine the specific product selection criteria that comes into play when making critical product selection decisions.

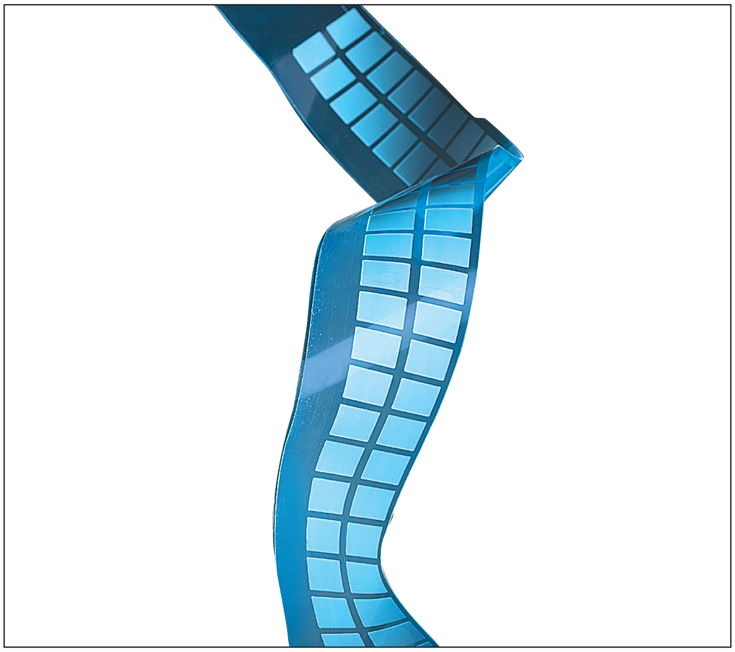
Thermal Interface Materials or TIMs play an important role in addressing the thermal limitations of electronic designs. They provide a heat path between heat-generating devices and cooling components. A thermal interface material is any kind of material that can be inserted between components to enhance the thermal coupling between them. For example, an electric vehicle has a battery pack that is generating heat that can be dissipated by placing a thermal interface material between the battery and a cooling plate that will help keep it in its operational temperature range.

Thermal conductivity is a measure of the ability of a material to transfer heat. Given two surfaces on either side of a material with a temperature difference between them, thermal conductivity is the heat energy transferred per unit time and per unit surface area, divided by the temperature.

Among the primary applications for TIMs are gap filling applications with pads and bonding applications with tapes. A TIM can be located between the heat sink and heat source, used to transfer heat from the heat source to the heat sink. LEDs, for instance are heat sources. Heat sinks can range from the traditional fin-shaped metal heat sinks to a chassis, a metal shielding can, backlight unit or housing case.

3M™ Thermal Interface Materials portfolio features 3M™ Thermally Conductive Tapes, 3M™ Thermally Conductive Interface Pads, 3M™ Thermally Conductive Grease, 3M™ Thermally Conductive Epoxy Adhesives, as well as 3M™ Thermally Conductive heat Spreading Tape.

3M™ Thermally Conductive Interface Tape solutions come in a variety of thicknesses, thermal conductivities, and bond strengths with different colors and tape constructions. 3M also offers thin 3M pads, with thickness between 0.2 and 2.5 mm at different thermal conductivity and hardness Shore values. In some assemblies where they are leaning toward thinner thermally conductive materials, products such as 3M™ Thermally Conductive Interface Tape 8926 and 3M™ Thermally Conductive Adhesive Transfer Tape 8805 down to 0.2 mm to provide not only the conductivity, but the high adhesion in an assembly where they may not have the room or space.



So, in applications where the assembly itself is relying on the tape for the final assembly, a high adhesion 3M™ Thermally Conductive tape will fill the bill. These tapes provide efficient thermal transfer for a wide range of applications including bonding heat sinks, heat spreaders, IC packages, power transistors, and more. They also offer a highly conformable construction that provides excellent wet-out on surfaces. As a rule of thumb the softer the material the better the wet-out. They also provide excellent handling and can be die-cut to fit most applications.

Thermal interface tapes, pads, and epoxies by 3M provide high thermal conductivity by focusing on the two areas that matter most: bulk conductivity and interface conductivity. They all address a crucial problem with today's electronic devices – the need to dissipate the sizable amounts of heat being generated.

Selecting the right thermal interface material is part art, part science. You have got to think about a given application's specific requirements to find the best form, fit, and function that will drive the best solution. It is not just selecting the best thermal conductivity (K-value). There is a lot of factors that come into play: gap thickness, electrical interference, industry requirements, and perhaps the substrates themselves.

When choosing a TIM solution, there are three features engineers must properly balance for better thermal performance. The first feature to consider is the TIM thickness. In general, thinner is better. However, if the TIM is too thin, it may have poor wet-out because it will not properly fill the surface roughness. There are applications where designers may have selected a very thick gap pad and had to greatly compress the material with mechanical fasteners to achieve the necessary thermal performance. It is better to match the actual gap thickness pressure and a material's Shore value (hardness) for the best form, fit, and function.

The TIM thermal conductivity (K-value) must also be considered. In general, higher thermal conductivity is used to dissipate greater amounts of heat. It should be noted, however, that as the thermal conductivity increases, the material may be harder because it has more conductive fillers inside. This will negatively impact the wet-out of the materials. The goal is to find the optimized balance of features to fit the application.

Gap thickness may be a factor: there are custom gaps that need to be filled and having the ability to make custom thicknesses of filler materials can be a keen advantage when trying to select materials that are form fitting and remove air pockets. There could be specific needs due to the roughness of the materials, the heat source, and the heat sink, that require dramatically lower Shore softness, so the material itself wets out better under lower compression.

What is more, there could be issues in the assembly process itself. For example, there are 3M™ Thermally Conductive Acrylic Interface Pads available in rolled formats for high volume rotary converting. This allows for lower cost during final assembly, in that the materials can be robotically applied, making it much easier to handle and use in the final assembly processes. The key point is this: time really should be spent understanding the application requirements to drive the best solution for a given application.

APPLICATION CASES

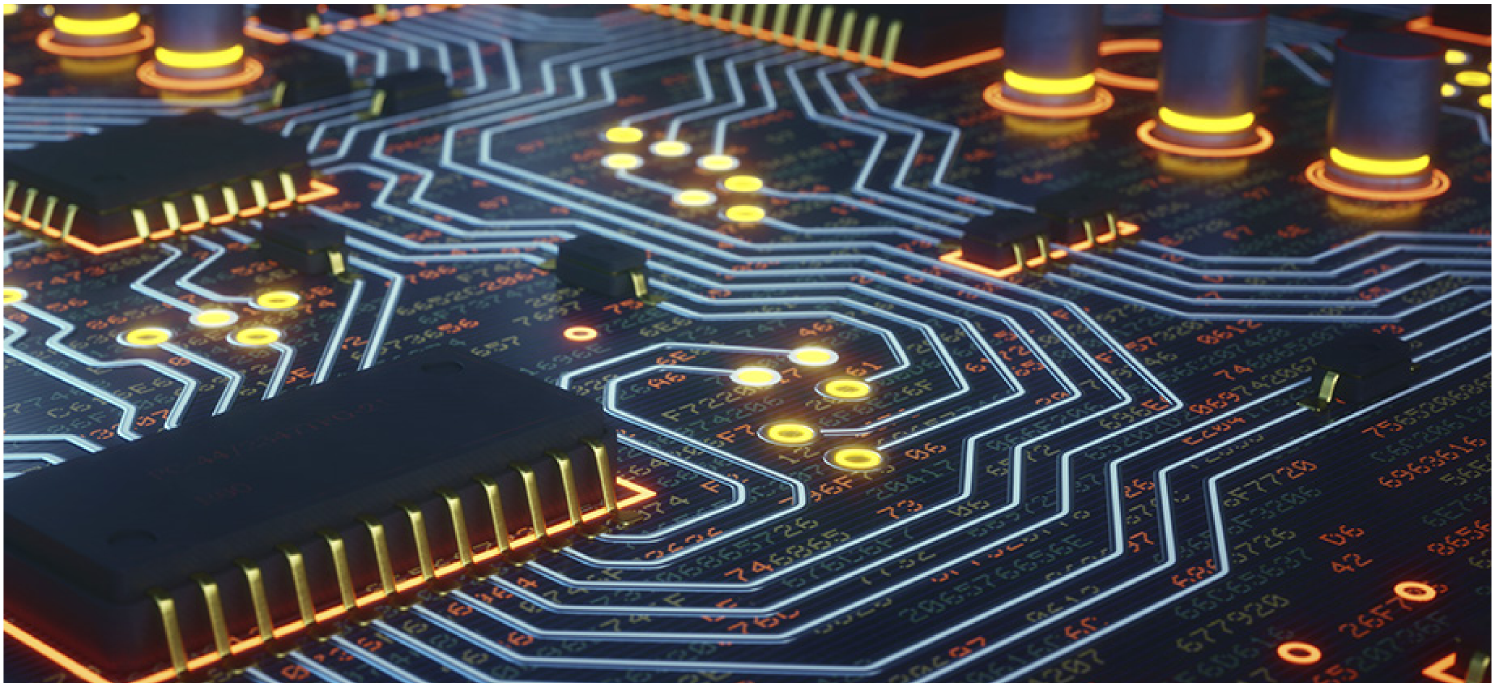
Let us highlight two markets where 3M Electronics Materials Solutions Division provides a wide range of product solutions. In the automotive marketplace, electric vehicles have moved to using thermal interface materials to keep battery packs running cool. Many of the electric vehicles of today utilize liquid cooling. And it is this interface between the heat-generating battery pack and the cooling heat sink or cooling plate where you will find thermal interface materials coupling those two surfaces to help keep the vehicle running at an optimal temperature. These drive trains are very energy efficient; they only lose 25% of their energy as heat, compared to internal combustion engines, which lose almost 80% of their energy to heat. However, this heat still needs to be dissipated, and so by coupling the battery pack and cooling plates with a thermal interface material, battery life can be extended, and the driving range of these electronic vehicles increased.

In the automotive market another key driver in hybrid electric and battery electric vehicles is light weighting. Here 3M offers an acrylic chemistry that is significantly lighter in weight than traditional silicone chemistries to help reduce the weight of the battery pack/battery module assembly. There are other needs for thermal interface materials: LED lighting for example, GCUs, ECUs, and other modules within the vehicle.

Customer input drives innovation, and one area where 3M has been putting a lot of attention and focus is in its acrylic interface pad portfolio. The company created and is offering acrylic interface pads that can withstand 130 C continuous temperatures. In many electronics designs this is very attractive for higher temperature applications that in the past had only been able to be fulfilled within a silicone portfolio.

3M™ Thermally Conductive Acrylic Interface Pads were developed specifically to manage and conduct heat. They deliver excellent dielectric strength and are suitable for use between heat-generating components and heat sinks as well as cooling plate applications. In this example, an OEM could select 3M™ Acrylic Pad 5571. First, the thermal requirements can be satisfied with the 3M Pad 5571's high thermal conductivity. At 2.0 W/m-K, this gap pad material can move heat and meet cooling requirements. 3M Pad 5571 is supplied in a rolled format which allows for high-speed rotary converting and lower converting costs.

Another example in the automotive marketplace is the electronic control unit (ECU). This device controls a broad number of complex functions within the vehicle, and, once again, involves thermal management. In these types of applications, you must think about things such as what is the gap and how much heat are you trying to move, but also assembly. There are two different types of assembly. The first assembly will end up having a printed circuit board assembled inside the case but is held in place with mechanical fasteners–perhaps screws, some



clips, even an epoxy–or it is formed in place. However, there are some applications where the thermally conductive tape not only has to move the heat but needs to provide high adhesion. The tape itself is going to hold the board into the module to help move the heat to its surrounding case.

In automotive, as was mentioned, light weighting the vehicle is always part of a design and is intended to extend the vehicle's driving range on a single charge. The 3M Pad 5571 is actually 20% lighter in weight than an equivalent silicone option. Thermal runaway is also an industry requirement, and it's a concern. So selecting materials like 3M Pad 5571 that have a UL 94-V0 rating for flammability would also be important for an electric vehicle battery pack assembly.

ELECTRIC VEHICLE PCB

This unique combination of heat management, heat conductivity and electrical insulation makes 3M's thermally conductive solutions a high-performance choice compared to silicone, with no siloxane outgassing.

In aerospace applications siloxane can affect displays and pilot vision by leaving a cloudy film on display surfaces. In the confined space of a cockpit, siloxane can build up on surrounding components or electronics, adversely impacting the pilot's ability to safely fly the plane. So if you could eliminate the siloxane outgassing within the cockpit area of the thermal interface materials that you're using, that would be a key benefit and of interest to design engineers. 3M has an extensive portfolio of acrylic-based thermal solutions that do not outgas siloxane, and are a preferred candidate for the confined spaces found in aircraft.

There could be an industry requirement for UL ratings for flammability, for outgassing, or the use of acrylic thermal pad chemistry over traditional silicone gap pad chemistry to reduce dramatically the amount of siloxane present in a thermal gap pad assembly. 3M™ Thermally Conductive Acrylic Interface Pads contain up to 1,000 times less detectable volatile siloxane content compared to silicone pads. The material is available in a variety of compression/recovery rates for very high wet-out on uneven substrates.

CONCLUSION

This paper has discussed electronic trends driving thermal management opportunities, how thermal materials work and how to dissipate unnecessary heat. Then we reviewed the application requirements of two important markets and some of the selection criteria that come into play to select the best TIM form, fit, and function. But please don't think that these solutions are just for automotive or aerospace, as they are just as likely to be relevant to the thermal projects that you are working on involving electronic devices and components.

For more information, contact TTI.