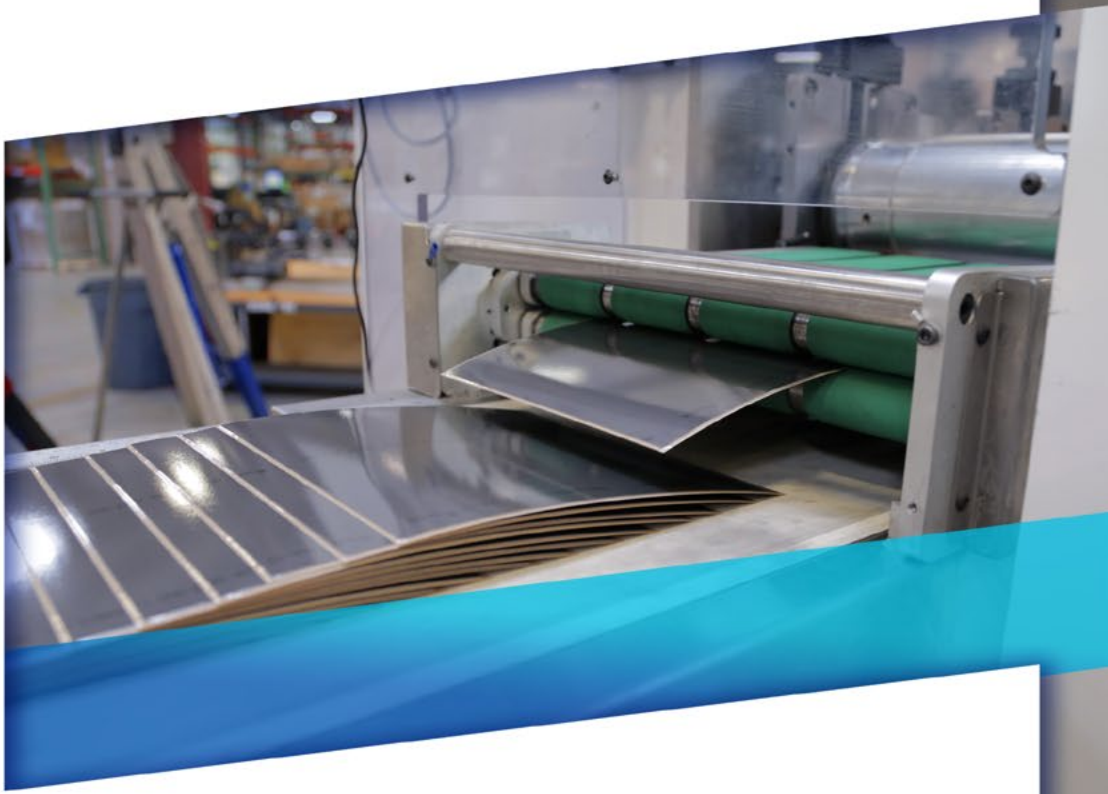
Thermal Management Solutions

for Electronic Applications



Users constantly demand more from their electronic devices. Now more than ever they want smaller, sleeker, lightweight designs that are capable of processing at optimal speed. They expect greater functionality, power, and data requirements— along with 24/7 usage. But all that increased power consumption generates heat, and excess heat inhibits performance and reliability, placing the intended operating life of the device in jeopardy.

To keep components cool, design and application engineers are tasked with finding the right thermal management solution. They must move excess heat away from critical components within the device, but they're challenged to do so within a smaller form factor.

With the demand for thermal management solutions on the rise, this paper takes a closer look at how to approach the challenge.

HOW IS IT DONE?

The process of heat dissipation is a rather complex subject, but it can be explained in basic terms that are relatively easy to understand. Thermal diffusivity, α, is a material parameter that describes how well heat flows through a specific material. As seen in **Equation 1** below, thermal diffusivity is based on the thermal conductivity, κ, density, ρ, and specific heat, C_P, of that particular material. Specific heat is the heat required to raise the temperature of the material by one degree. So, when selecting the right material for thermal management, these factors of thermal diffusivity must also be considered.

Equation 1: $$\alpha = \frac{\kappa}{\rho * C_P}$$

When it comes to the design of thermal management, different techniques are used to minimize or transfer heat, from heat sinks to heat spreaders and heat shielding.

HEAT SINK

A heat sink, which artificially increases the surface area, uses a series of fins and pins and is typically combined with an airflow system. Usually made of copper or aluminum, it must be a good conductor of heat to allow for optimal heat dissipation. Thermal interface materials are used to improve the performance of the heat sink by filling surface imperfections between the heat source, heat spreader, and heat sink. Some examples of materials that would help achieve this include gap fillers, phase change materials, thermal greases, and flexible graphite.

HEAT SPREADER

Another common cooling device is a heat spreader, which moves the heat and distributes it over a wider area, typically across the surface. It attaches directly to the heat source and spreads the heat over a large area, often using the device enclosure as a heat sink. Flexible graphite and thermally conductive heat spreading tapes are both examples.

HEAT SHIELD

Finally, a heat shield comes into play when there is a need to reflect or absorb heat to alleviate an overheating problem or reduce a surface hot spot. While heat shields work similarly to heat spreaders, they are not directly attached to the heat source and act primarily as preventive insurance against heat buildup.

WHAT ARE THE FACTORS TO CONSIDER?

Every thermal management situation is different, so there's no one-size-fits-all approach to selecting the right technique or material. To provide a design option that works, it is important to first:

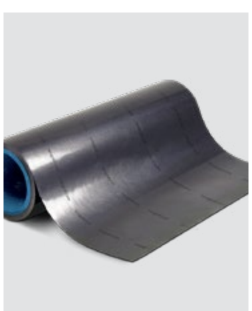
- **Understand the objective.** What is the problem you need to solve? How will success be measured? What are the metrics?
- **Look at the design constraints.** How much space is there? How important is weight? These and other considerations dictate the thickness of the thermal management solution.
- **Examine the performance requirements.** This is where the thermal conductivity comes in.
- **Factor in the cost.** A bigger budget opens the door for a sleeker, high-performance solution. But certain consumer electronics, such as cell phones and laptop computers, for instance, are extremely competitive and price-sensitive, and that's when we work in tangent with your engineers to bring the cost down.

One resource you may not have considered in your search for the perfect thermal management solution is your flexible materials converter. Because converters like JBC Technologies work directly with many different material manufacturers, we have a unique perspective on the challenges design engineers are trying to solve and the breadth of available solutions.

WHAT ARE THE MATERIALS?

As previously mentioned, devices don't perform well when they overheat. One way to mitigate the problem is to transfer heat away from the device, such as from a microchip or board to a heat sink. Different materials are used to accomplish this task—from flexible graphite to thermal interface materials such as thermally conductive gap pads and transfer tapes. Depending on your design objective, other solutions might include polyimide films and aluminum.

The following pages present a deeper dive into some of these materials.

Flexible Graphite

An all-around choice

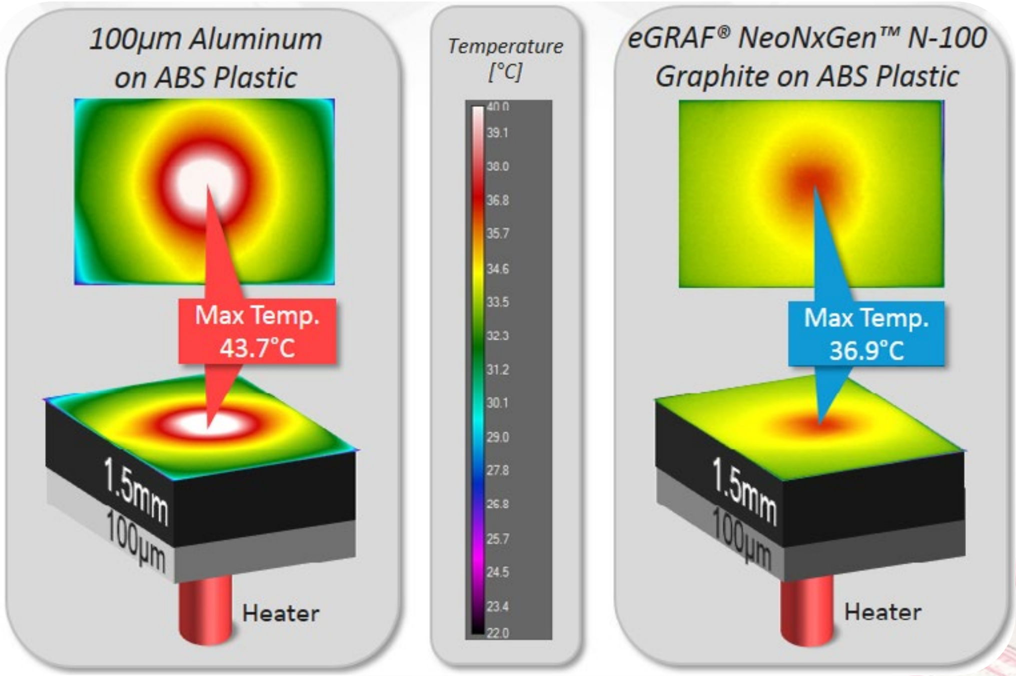
Based on the equation for thermal diffusivity described above, graphite is a prime candidate for a thermal management system application. Graphite is known for its high thermal conductivity and low density, which leads to high thermal diffusivity. It is also relatively lightweight. Graphite's hexagonal, layered crystal structure results in high conductivity, which is caused by the delocalized bonding between the layers. This layered structure also leads to high amounts of anisotropy, meaning the properties vary in different directions. As a result, when graphite is correctly oriented, its thermal conductivity is higher in the planar direction of the structure compared to the stacking direction, via weak interlayer binding energy. This makes graphite an excellent material choice for thermal management systems. When applied, this allows heat to spread evenly across the full surface area, but it limits heat flow through the part's thickness.

In less technical terms, graphite is like a sheet of paper with thermal conductivity several times that of copper or aluminum, although it's a fraction of the weight. From an interface perspective, graphite is typically available in simple peel-and-stick solutions—and the peace of mind that it won't fail. This is important when user comfort comes into play and for no-fail scenarios such as zero-downtime servers.

"Graphite spreads heat in the plane, but it also shields the heat *through* the plane."

-Jon Taylor,
Product Manager at
NeoGraf Solutions

SURFACE TOUCH TEMPERATURE COMPARISON



"If a device surface is too hot, graphite is a great solution because it can spread heat out to lower the temperature," said Jon Taylor, product manager at NeoGraf Solutions. "But graphite also has low thermal conductivity through its thickness, so it shields heat from the user or another temperature-sensitive component."

Today, although graphite is used widely in cell phones and other electronics, it's still often misunderstood. It is:

- **Passive** and works alone to accomplish the task, without the need to provide power or control it
- **Flexible** in that it works at any temperature
- **Higher in thermal conductivity** but weighs less than aluminum or copper

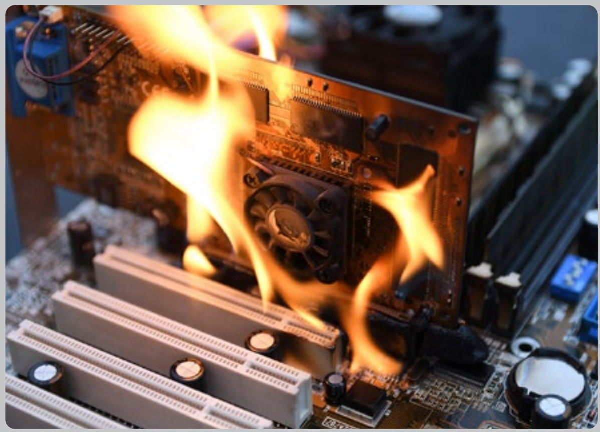
Graphite checks all three boxes:

✓ ***ultra-thin*** ✓ ***high performance*** ✓ ***ultra-lightweight***

Basically, graphite can be used for any kind of thermal management.

Graphite in Action

When the processor and graphics card in a computer exceed the normal operating temperature, the excess heat needs to be dissipated. Attaching a piece of flexible graphite to the surface of the chip effectively increases the surface area for cooling and keeps the temperature low. Inversely, the chip may be running fine, but the laptop may be positioned on the user's leg where it can get very warm. In this case, rather than attaching the graphite directly to the heat source, it is placed on the inside of the plastic cover on the bottom of the laptop. Here it acts as a heat shield to protect the user. Heat from the CPU enters the graphite, which spreads the heat evenly over a large surface so it is no longer concentrated in one area. This creates a much cooler surface on the bottom of the device.



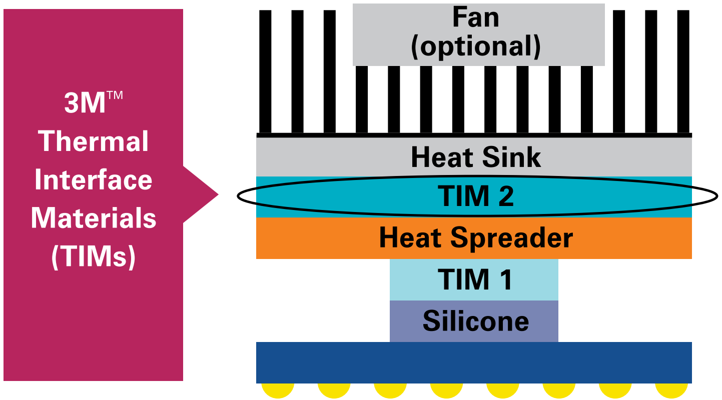
Thermal Interface Materials

Solutions for the toughest design challenges

Thermal interface materials are another option for mitigating heat buildup. Examples include thermally conductive adhesive transfer tapes, thermally conductive acrylic or silicone pads, and thermally conductive epoxies and greases.

Thermally conductive tapes are used for high adhesion while the pads are well suited to gap filling. If there's not enough space for a secondary clip or screw, high adhesion tapes can be used to provide the bond strength. Gap pads are used when there is extra space that requires more cushioning, but without the need for higher adhesion. Highly conductive tapes are important for assemblies that have to rely on the tape itself to hold the assembly together. With their high adhesion, they can bond substrates together permanently.

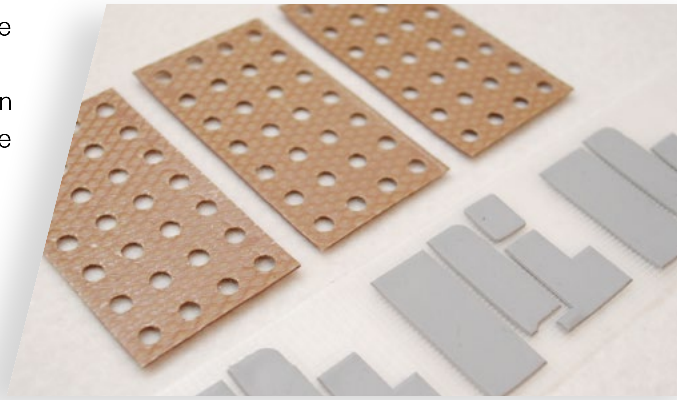
"Heat spreading tape takes the heat and spreads it on a horizontal plane that dissipates it, allowing the electronic device to run cooler. This is an interesting product because it starts by taking the heat from the heat source, but instead of passing through the tape, the tape itself acts as a heat sink."
-Joe Petri
3M Account Manager



"3M™ Thermally Conductive Heat Spreading Tape 9876 takes the heat and spreads it on a horizontal plane that dissipates it, allowing the electronic device to run cooler," said Joe Petri, account manager in the Electronic Materials Solution Division at 3M. "This is an interesting product because it starts by taking the heat from the heat source, but instead of passing through the tape, the tape itself acts as a heat sink."

3M™ Thermally Conductive Interface Pads are thermally conductive, with both acrylic and silicone chemistries, and are typically used for filling larger spaces. There's usually also a physical clamp, screw, or clips that hold the overall assembly together. It's important to keep in mind that the two types of pads—silicone and acrylic—are suited to certain applications.

Acrylic and silicone pads both function as great choices for thermal interface materials. Both of these materials are polymers, meaning they are made up of many small repeating units, or monomers, that come together to form a long-chain molecule. These long chains of atoms, which are connected by strong covalent bonds, are ideal candidates for heat flow. The covalent bonds found in these materials act as connection cables that allow the heat to flow through the material with ease. So while these materials are not ideal to shield or block heat, they perform tremendously well in applications where heat flow is desired. As previously mentioned, one of these applications is a thermal interface pad, which functions as an interfacial layer that transfers heat between two outer layers.



"What's unique about acrylic chemistry is that in some applications it would be a better, lower halogen solution," Petri explained. "People do not want silicone or siloxane present in their final assembly, especially in medical devices, automotive, aerospace or military. 3M™ Thermally Conductive Acrylic Interface Pads have very minute traces of anything like that in the final product."

The acrylic chemistry is appealing to OEMs because it has the same thermal conductive performance as traditional silicone products, but without siloxane. Other advantages include:

- Excellent dielectric strength
- Similar strength and flammability performance as traditional silicone gap pads (all UL listed)
- Excellent electrical insulation properties to protect against electrical interference and device breakdown
- Being lightweight, which makes them ideal for applications with smaller footprints
- Lower cost
- Availability in rolls versus sheets, resulting in better production yields for the die-cutter and lower costs for the OEM

Thermal interface materials are effective agents when it comes to improving device reliability and extending component life. They can meet some of the toughest design challenges associated with excess heat and performance.

Foils, Papers and Films

Thermal and electrical combined management

When a thermal management system is needed for an application in today's engineering landscape, the other major consideration is the electrical management of the system. In today's small electronics, both the thermal and electrical management systems play a key role in the overall functionality of the device. Typically, one is not present within a system without the other.

When it comes to combined thermal and electronic management, a variety of materials can be used.

FOILS

Foils are typically a good choice for thermal and electrical shielding applications. They present a low-cost solution that can significantly lower surface temperatures due to radiant heat. Aluminum is an excellent conductor of heat and electricity, due to high conductivities. Its low density makes it relatively lightweight, which helps explain the widespread use of aluminum foil for thermal and electrical management.

PAPERS

Papers are another type of material used for thermal and electrical insulation, specifically dielectric papers. Dielectric materials are very poor conductors of electric current. This is due to the lack of loosely bound, free electrons, which makes it difficult for an electric current or thermal radiation to easily pass through the material. Dielectric papers offer good mechanical properties and wear resistance, so they're both durable and flexible.

In recent years, aramid fiber paper has become the standard dielectric paper due to the combined benefit of high heat resistance and electrical insulation. One major point to consider when it comes to dielectric papers is that they are hygroscopic, meaning they tend to absorb moisture found in the air. As the papers absorb moisture, their mechanical and physical properties tend to change. This reactive nature in humidity must be assessed for applications that take place in a humid environment.

FILMS

Dielectric films are also used for thermal and electrical insulation. Non-conductive plastic films offer insulating properties without all the side effects from temperature and moisture. These plastic films are primarily made of long-chain carbon molecules, and they lack the highly electronegative bonding sites necessary for reactivity to humidity and other chemicals. Although they are more cost prohibitive, these films provide greater stability when environment changes are prominent for the given application.

Polyamide, or nylon, films offer protection over a broad temperature range, which is important for applications that desire a functional range of temperatures. These polyamide films have high melting points, great strength and toughness, and good oxygen barrier properties. When all these properties are considered, polyamides provide a solid option for thermal and electrical management if the application demands better performance metrics.

CLOSING

From choosing the right materials to identifying the most effective approach, thermal management is a complex challenge that varies with every situation. As consumers continue to demand more from their electronic devices, it's safe to say the problem of increased power consumption and excess heat won't be going away any time soon. Today more than ever, however, it's good to know there are a growing number of resources—including the flexible material converting specialists at JBC Technologies—to help you take on this task.

About JBC Technologies

As a full service manufacturing partner, JBC Technologies provides innovative die cut solutions that solve critical challenges for thermal management, gasketing, sealing, heat shielding, buzz, squeak and rattle/NVH, and more. But the impact of what we do goes far beyond converting flexible materials into custom parts. Drawing on the diverse talents of our team, we deliver supply chain optimization, engineering innovation, and manufacturing excellence—creating partnerships with our vendors and customers to ensure success.

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