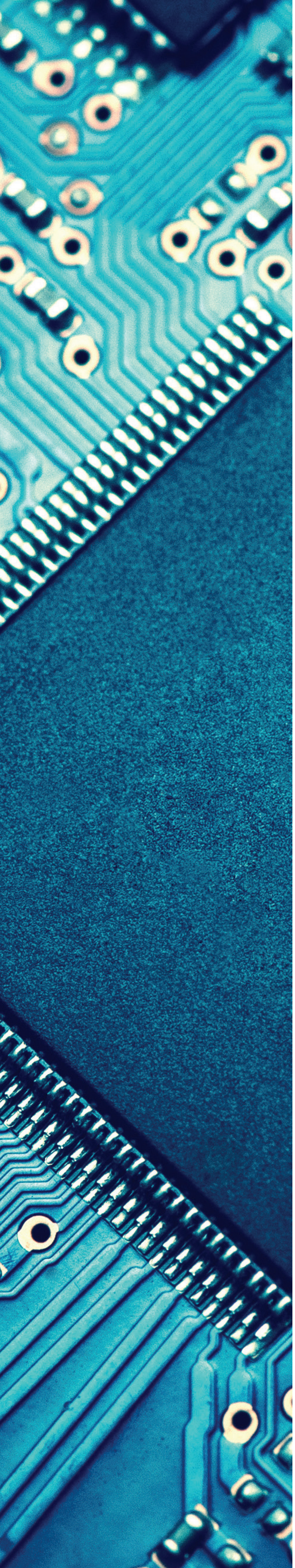

MASTERBOND®
TECH SPOTLIGHT

# Ultra Low Thermal Resistant Adhesives for Electronic Applications

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# Ultra Low Thermal Resistant Adhesives for Electronic Applications

Thermally conductive adhesives are uniquely qualified to meet the increasingly diverse requirements of advanced electronics systems. From their traditional use as fastening materials, adhesives find wide application in bonding and encapsulation in nearly every application segment, including military/aerospace, medical, automotive, and industrial, among others. In their traditional application in computer and communications systems, thermally conductive adhesives have long played a vital role at the chip level for die attach, at the PCB level for heat sink bonding, and at both the chip- and board-levels for all types of thermal management methods.

As the semiconductor industry pushes toward smaller, higher density devices, product manufacturers face greater challenges in assembling die, package, and other components into products able to cope with increasing heat loads. Further complicating this critical manufacturing step, each product not only presents growing thermal requirements but also must meet unique manufacturing and lifecycle requirements dictated by the needs of the application. With advances in epoxies, silicones, and other materials, however, manufacturers can find adhesives able to meet nearly any combination of requirements for thermal, environmental, and structural stability.

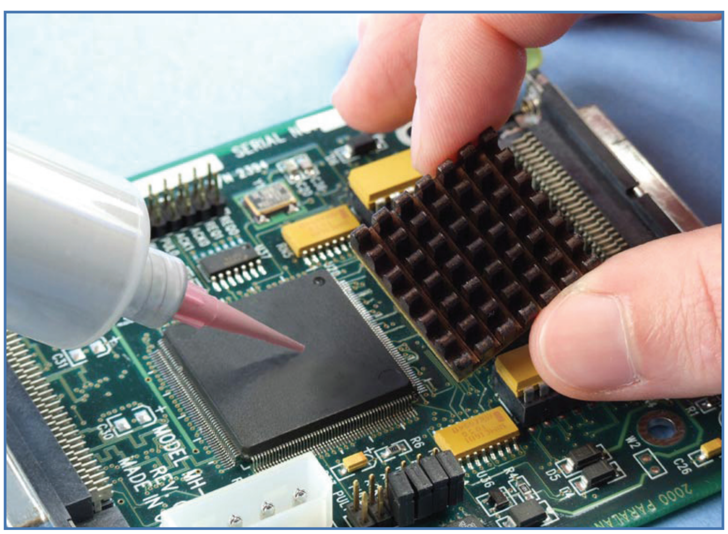

*Figure 1: Thermally conductive adhesives help facilitate heat dissipation in nearly every application segment, ranging from die attach to traditional heat-sink bonding.*

Advances in semiconductor process technologies continue to yield faster high-density devices that often increase heat loads in target designs. The ability of thermally conductive adhesives to help dissipate heat has motivated their use as the preferred fastening approach in applications requiring careful thermal management (Figure 1). Besides their use in areas such as power electronics and solar energy, thermally conductive adhesives play a vital role in the rapid growth of the LED lighting industry. Since light output falls as temperatures rise, the thermal conductive properties of adhesives are particularly important in this arena. By using these adhesives, LED providers are able to deliver highly efficient LED lighting products. Furthermore, because these adhesives remain resistant to typical environmental stresses such as weathering and corrosion, these products can help deliver the extended operating life expected in the marketplace.

## Manufacturing requirements

In supporting highly diverse application segments, adhesives can deliver a correspondingly broad array of performance characteristics required for manufacturing suitability, structure support, and protection. For example, during manufacturing, adhesives need to flow freely to prevent formation of voids yet provide minimal curing times to help speed the overall manufacturing process (Figure 2). At the same time, adhesives need to adhere firmly to surfaces, providing a strong bond between heat sinks and components for PCBs or between a die and package for integrated circuits. In fact, the interface between die and package faces can experience some of the most significant stresses in an electronic assembly. When two dissimilar materials are bonded, differences in the coefficient of thermal expansion (CTE) in the materials can result in stress and strain that might eventually weaken or even fracture the bond between them. Even normal device operation can cause thermal cycling that can add stress to this bonding interface. By providing adhesives with the right CTE, engineers can reduce thermal expansion mismatches between die and package, thereby reducing the stress while providing necessary structural support for the assembly.

## Thermal challenges

In the face of growing demand for more effective thermal management, engineers are looking for adhesives correspondingly more effective in conducting heat away from sensitive devices and entire assemblies. Adhesive suppliers typically specify a material's thermal properties in terms of bulk thermal conductivity, which describes the material's ability to transfer heat through itself. In electronic design, however, thermal management remains focused less on material specifics than the broader issue of dissipating or transferring heat from a die through a package or from a component through a heat sink.

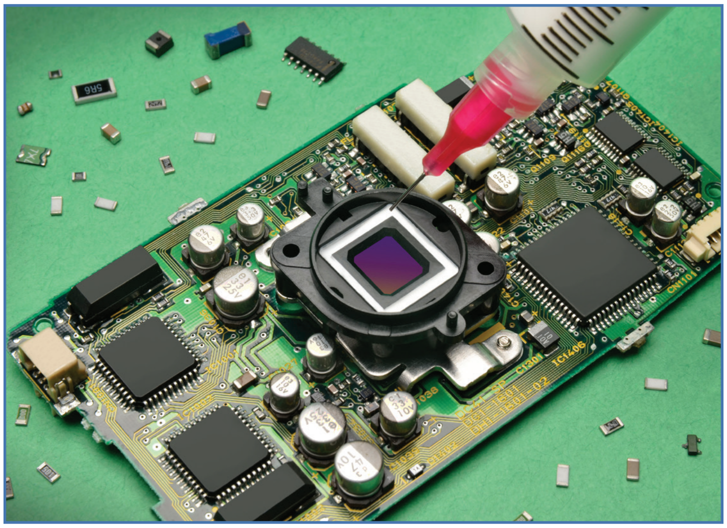

*Figure 2: Fast curing, free flowing thermal conductive adhesives fill gaps and provide high mechanical strength properties in critical electronic assembly applications.*

For an engineer, the internal heat transfer capability described by the bulk thermal conductivity specification addresses only part of the real objective. In a typical product assembly, a more practical characteristic is the material's thermal resistance. Thermal resistance describes the ease with which heat can transfer across the interface between the die (or component) surface and bonding material, across the bonding material, and finally across the interface between the bonding material and package (or heat sink).

In any product assembly, whether it is a die attached to a package or component attached to a heat sink, the thickness of the bond and nature of the surfaces meeting at the bond interface can work to impede heat transfer. Indeed, Fourier's law of heat conduction dictates that the rate of heat flow across a medium is inversely proportional to the thickness of the medium. Consequently, manufacturers look to join materials with the thinnest-possible bond lines. In fact, a thin bond line is preferred over a thick one, since it not only helps in reducing the thermal resistance, but also imparts lesser stress at the corners of the bond joint. Furthermore, a thin bond line results in less air cavity concentration compared to a thick one (Figure 3).

## Tuning with fillers

Engineers can find adhesives able to meet a broad array of manufacturing requirements thanks to the use of filler materials in adhesives. In fact, adhesive suppliers can tune adhesives to meet specific performance demands by changing the type of filler material, using different filler particle sizes and shapes, and varying the ratio of filler to base material (filler loading).

The use of fillers is particularly important for optimizing the thermal properties of adhesives. In their base composition, epoxies, silicones, and other adhesive systems are inherently thermally insulating — exhibiting a bulk thermal conductivity around 0.10 to 0.20 W/(m•K), about the same as a piece of plexiglass. In contrast, the use of fillers in materials such as Master Bond's Supreme 18TC epoxy system improves thermal conductivity by a factor of 20 or more compared to base compositions.

In general, larger particles, different particle shapes, and higher filler loading can increase thermal conductivity, but the interplay between the characteristics of the filler and base adhesive is complex. Beyond filler composition, different filler materials such as metal, ceramic, and graphite enable adhesive suppliers to deliver adhesives highly optimized for specific applications. For example, the silver filler used in Master Bond's Supreme 10HTS epoxy system results in extremely low volume resistivity for assemblies requiring high electrical conductivity. Similarly, the graphite filler in Master Bond's EP75-1 epoxy allows it to dissipate static electricity or provide shielding for RF designs.

In practice, however, the impact of filler type, particle size, and loading extends well beyond any single characteristic such as thermal or electrical conductivity. Through careful selection of filler type, particle composition, and loading, adhesives suppliers can dramatically modify viscosity, curing time, strength, CTE, and any number of characteristics.

Furthermore, by raising or lowering filler loadings, suppliers can increase or decrease viscosity of the adhesive. Fillers in the Supreme 18TC system, for example, allow it to be applied in ultra-thin bond lines — as low as 10-15 microns (about 0.0004 to 0.0006 inches). The resulting adhesive combines the ability to join very complex shapes with the kind of very low thermal resistance characteristic required to extend electronic device performance, service life, reliability and integrity.

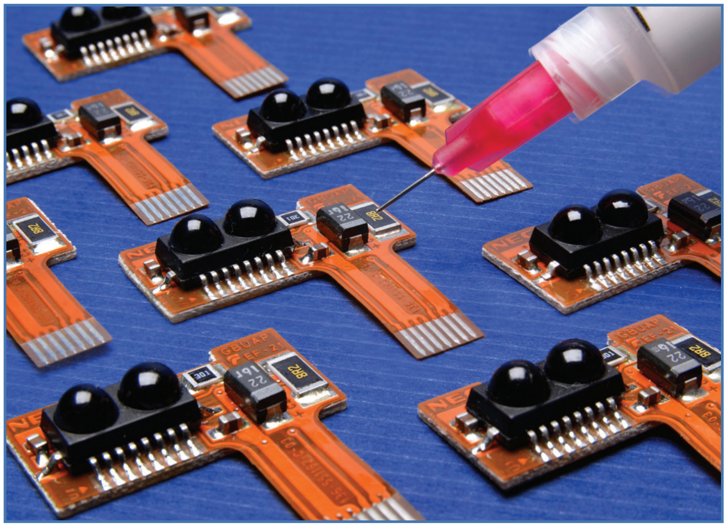

*Figure 3: Consistent, uniform thin bond lines maximize heat transfer and ensure reliable device performance.*

Because of its dramatic impact on adhesive properties, filler technology occupies ongoing attention from researchers in both industry and academia. Besides exploring the impact of characteristics such as particle size and shape, filler-technology experts are experimenting with next-generation filler materials. Although commercial products based on these materials may be years away, fillers based on graphite or graphene nanoparticles show promise in enabling adhesives to achieve significantly higher thermal conductivity at lower loading levels than available with today's fillers. With the trend toward even higher performing electronic products, the need for next-generation thermally conductive adhesives continues to grow in urgency.

## Conclusion

Although thermally conductive adhesives have long played an important role in electronics manufacturing, industry trends are driving a more critical need for these materials. For fast-growing segments ranging from high end electronics to LED lighting and more, engineers need materials able to dissipate more heat from advanced electronic devices. In this environment, thermally conductive adhesives not only support a wide range of thermal management requirements but also meet equally challenging requirements for manufacturing assembly and extended product lifecycles.

For further information on this article, for answers to any adhesives applications questions, or for information on any Master Bond products, please contact our technical experts at Tel: +1 (201) 343-8983.