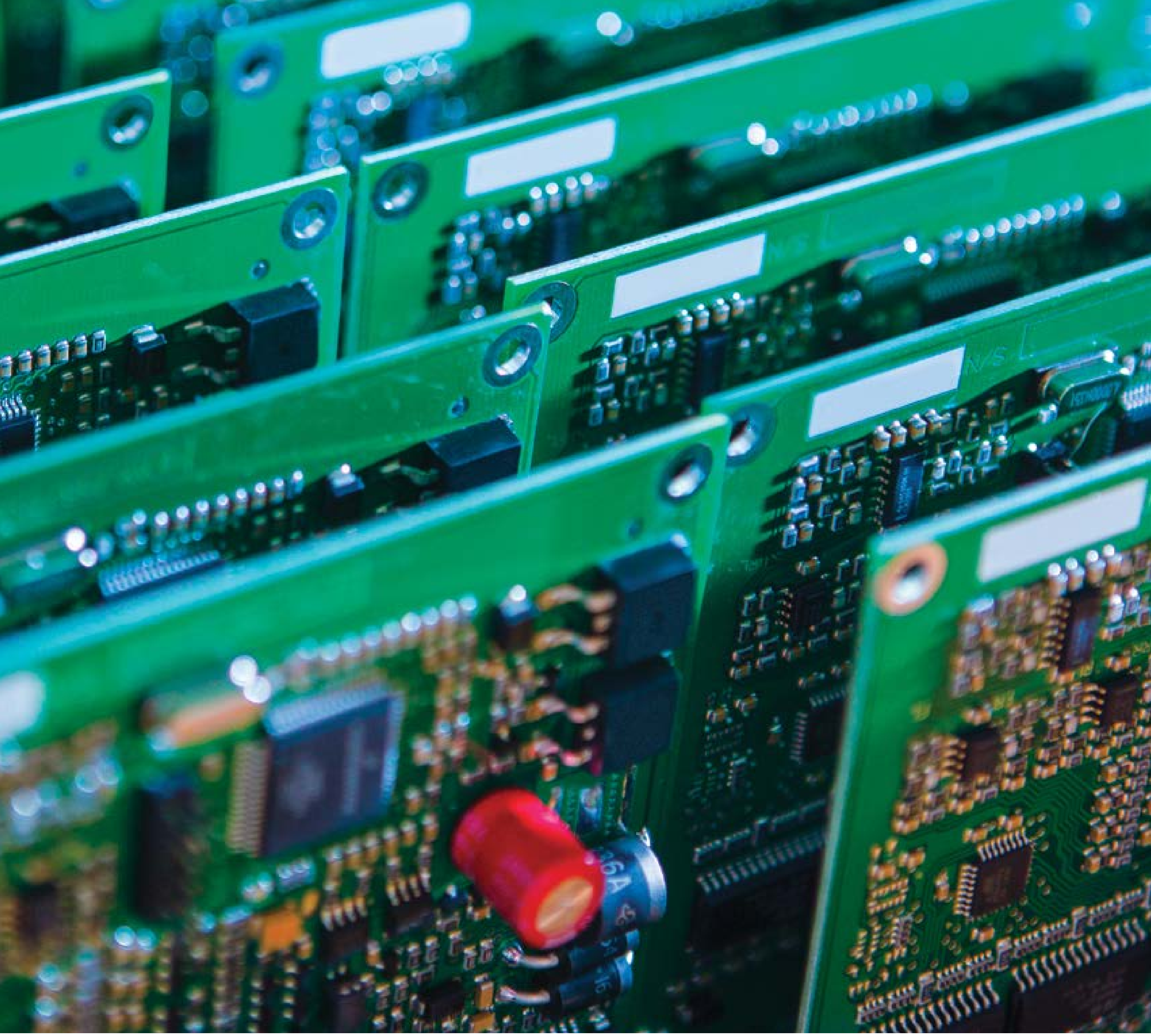

Thermal Interface Materials
Choosing Between Gels and Gap Filler Pads

Parker Chomerics

ENGINEERING YOUR SUCCESS.

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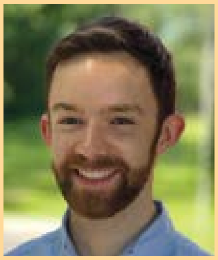

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Introduction

As each new electronic product generation requires higher power in smaller packages, the challenges associated with thermal management have become more intense. Two general types of thermal interface materials – gels (or dispensable gap fillers) and gap filler pads – are used by design engineers for displacing air voids and ensuring proper heat transfer, and each has distinct advantages depending on the application. This white paper analyzes and draws conclusions about key performance and manufacturability characteristics in both gap pads and new advances in gels.

Contents

Overview: Heat Transfer Fundamentals

The objective of thermal management in electronics packaging is the efficient removal of heat from the semiconductor junction to the ambient environment.

Thermally conductive materials are used to eliminate air gaps or voids from adjoining rough or uneven mating surfaces. Because the thermal interface material has a greater thermal conductivity than the air it replaces, the resistance across the joint decreases, and the component junction temperature will be reduced.

A variety of material types have been developed in response to the changing needs of the electronics packaging market in applications such as telecommunications equipment, consumer electronics, automotive electronics, LEDs/lighting, power conversion, power semiconductors, desktop computers/laptops and servers, handheld devices, memory modules and vibration dampening. This white paper explores the properties and most effective uses of two principal "gap filler" thermal interface materials: **gels** – also known as dispensable gap fillers – and **gap filler pads.**

This process can be separated into three major phases:

1. Heat transfer within the semiconductor component package
2. Heat transfer from the package to a heat dissipater (the initial heat sink)
3. Heat transfer from the heat dissipater to the ambient environment (the ultimate heat sink)

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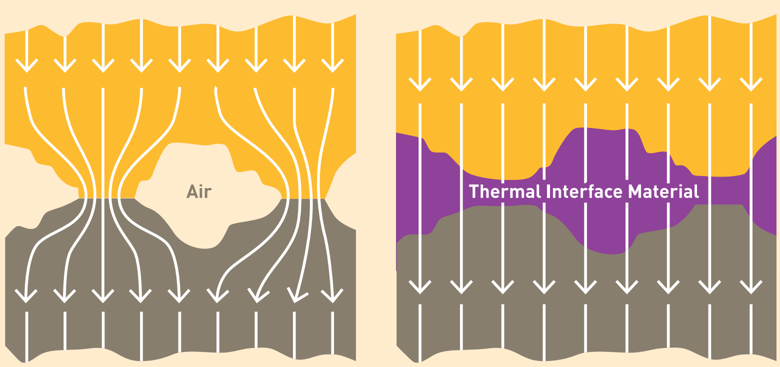


Thermal Interface Material Basics

This illustration represents two surfaces in contact and heat flow across the interface without (left) and with thermal interface material applied.

Overview: Heat Transfer Fundamentals continued

The first phase is generally beyond the control of the system-level thermal engineer because the package type defines the internal heat transfer processes. In the second and third phases, the packaging engineer's goal is to design an efficient thermal connection from the package surface to the initial heat spreader and on to the ambient environment. Achieving this goal requires a thorough understanding of heat transfer fundamentals as well as knowledge of available interface materials and how their key physical properties affect the heat transfer process.

When evaluating thermal interface materials, design engineers seek to identify high-performance products that meet the thermal, design, manufacturing and cost challenges inherent in each customized application. These thermal material drivers include:

- Thermal impedance
- Thermal conductivity
- Compliance and conformability
- Reliability
- Adhesion
- Ease of handling, application and use
- Service life

Industry applications where gels and pads are commonly used.

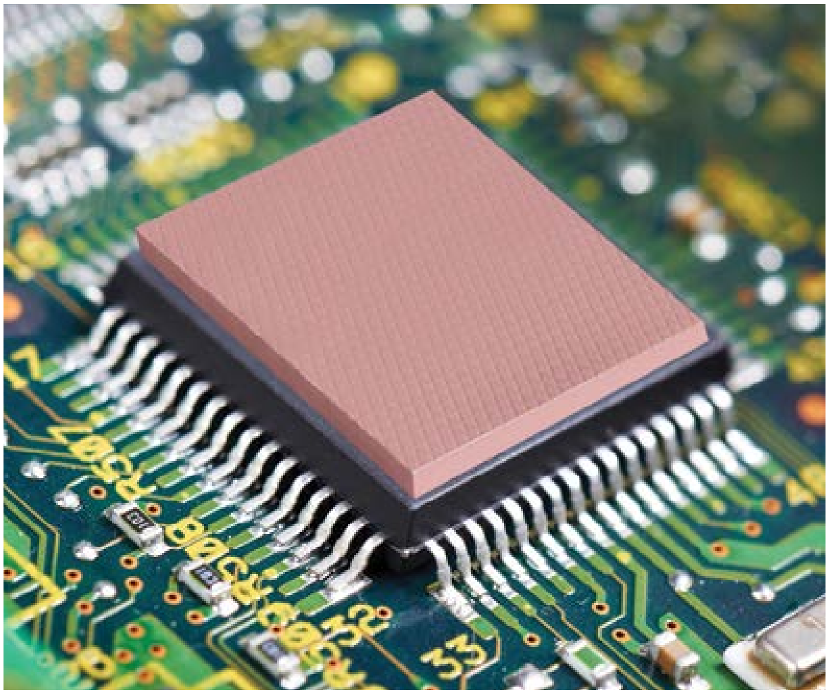
- **Life Science**
- **Military/Aerospace**
- **Telecom**
- **Automotive**
- **Information Technology**
- **Renewable Energy**
- **General Industrial**

Introduction to Gap Filler Pads and Gels

Gap Filler Pads: The Basics

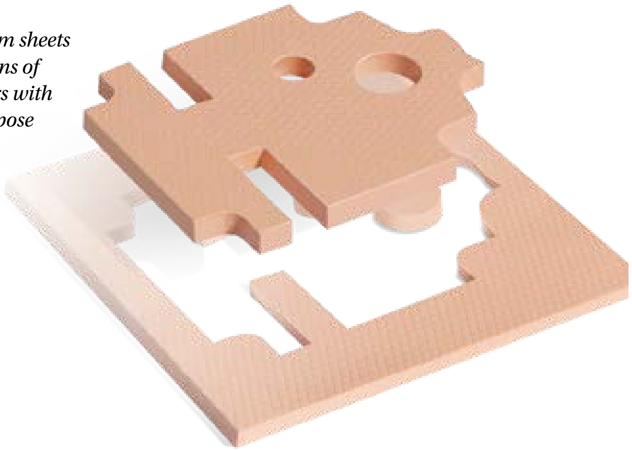
Thermally conductive gap filler sheets and pads offer excellent thermal properties and high conformability at low clamping forces. Key features and benefits include:

- High conformability
- Ultra-low deflection force
- High tack surface to reduce contact resistance
- Minimal component stress
- Reduced "hot spots" on printed circuit board
- Thicker pads can improve vibration dampening
- Can "blanket" multiple components



Thermally conductive gap filler pads are cut-to-shape and applied manually to offer thermal properties and high conformability at low clamping forces.

Pads are cut from sheets of various options of material carriers with peel liners to expose the tack surface.

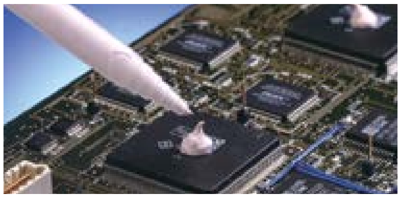


Gels: The Basics

"Gels" – the dispensable gap fillers that are highly conformable, pre-cured, single-component compounds – feature a cross-linked gel structure that provides long-term thermal stability and reliability. Key features and benefits include:

- One-component dispensable
  - Eliminates multiple part sizes/numbers
  - Aids in automation
- Fully cured
  - Requires no refrigeration
  - No mixing or additional curing
  - No settling in storage
- Highly conformable at low pressure
  - Applies minimal stress, making it effective for delicate components
- High surface tack

Parker Chomerics THERM-A-GAP™ GEL 37 is a dispensable thermal gap filler that can be applied fully cured in custom geometric shapes depending on the application.



Dispensable gels can be applied manually (Parker Chomerics GEL application, left) or through a semi- or fully automated system for high-volume applications.

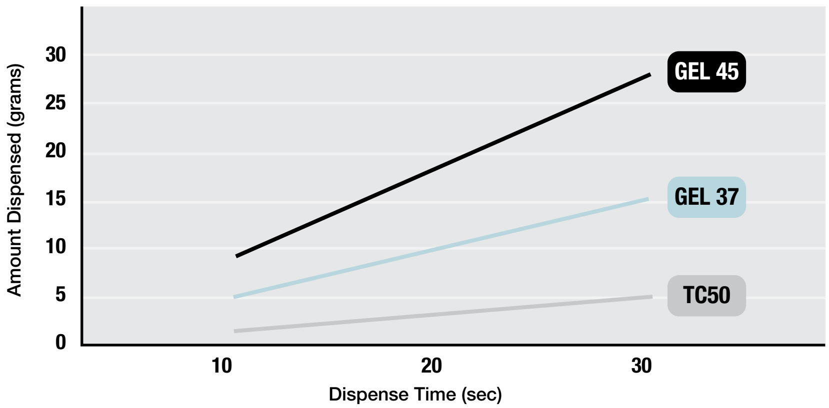
Pads vs. Gels – Understanding Key Differences

Both pads and gels have proven to be effective means of thermal management in many industries and applications. While pads have a longer proven track record, recent advances in gels have closed the performance gap and, in some cases, surpassed the performance of pads. Following are ways newly engineered gels compare to gap pads in matters of critical importance to design engineers:

Performance Characteristics

- **Conformability –** Both gels and pads are conformable to a degree, but the maximum configurability of a gap pad is less than that of a gel due to its solid structure.
- **Flow rate –** The goal when developing gels is to achieve the highest and most repeatable flow rate. Customers want to be able to set their dispensing equipment for the same flow rate batch-to-batch to maintain a consistent volume of material and avoid waste. Newer gel technologies achieve a more repeatable and higher flow rate that improves throughput and reduces waste.
- **Thermal conductivity –** Identifying the amount of heat [Watts] in need of dissipation will determine the thermal conductivity performance needed in that application's gap filler. This is usually calculated and measured in Watts per meter Kelvin, or W/m-K. The higher the value, the more heat the material can theoretically dissipate.

GEL FLOW RATE DICTATES AMOUNT DISPENSED*



* Flow Rate for each material is published as grams/min using a 30 cc syringe with no tip attachment, 0.100" orifice, 90 psi (621 kPa)

The flow rate of a Gel material dictates how much material can be applied in a given length of time. Shown are three popular Parker Chomerics Gel materials with corresponding flow rates and amount dispensed in 10, 20 and 30 seconds under standard conditions.

Industry-wide, thermal conductivity of gap pads and gels can range from 1 to 10 W/m-K.

- **Long-term reliability –** While this issue might be the great unknown in real-world applications because of the newness of advanced gels, rigorous accelerated aging tests can be used to help assure long-term reliability.

Three different aging treatments can be performed on a fixture comprised of the gel compressed between two stainless steel panels. One is a dry heat soak at 125° C. The second is heat and humidity at 85° C at 85% relative humidity. The third is temperature cycling from -40° to 125° C. Future state, a thermal shock element is added, which is another -40° to 125° C. But instead of having a gradual ramp and hold, it changes over the course of 10 seconds from the two extremes and holds for a shorter period. This is generally considered a more destructive or more challenging test. Vibration testing is also performed based on the GMW3172 test standard.

continued next page

- **Curing –** Curing is the irreversible chemical reaction that joins the polymer chains in the thermal interface material. Cross-linking refers to relatively small molecules joining much larger polymer chains. So, while both pads and gels cure via the same cross-linking mechanism, in a pad there are more cross-links, which leads to a stronger cure. Curing contributes to the viscoelastic properties of gels which improves their form stability over a non-cured system. Finally, there are non-cured single-component dispensable materials, whose polymer components are already in their inert, fully reacted states and nothing needs to be added to cause them to react further.

Manufacturing/Assembly/ Cost Dynamics

- **Automation –** The opportunity for automation is a significant advantage for gels because dispensing systems are quite versatile. While pad placement can be automated to an extent, the equipment and fixturing required to do so is typically quite specialized and may not be readily

	Bench-Top Dispensing Systems	High-Volume Dispensing Module	
		Cartridge Pumping and Robotic Dispense System	Pail Pump and Transport System
Features & Benefits	Repeatable shot size and shape, programmable XYZ direction and speed, continuous dispensing, low capital investments	Fastest cycle type, lowest material cost, visual inspection systems, fully automated system, best control and yield, continuous dispensing, repeatability in shot size & shape	Fastest cycle type, lowest material cost, visual inspection systems, fully automated system, best control and yield, continuous dispensing, repeatability in shot size & shape, multi-process step
Operator Responsibility (Post Programing & General System)	Seating application under dispensing head	Purging dispense system between materials	Purging dispense system between materials
Variability in Dispensed Part	None		

	Jar or Container	Manual Hand Dispensing		Cartridge Caulking Gun			Shot Size Controllers	
		Single Component Syringe	Mixpac™ with Static Mixer	Manual	Battery Powered	Air or Pneumatic	Pressure/Time	Positive Displacement
Features & Benefits	No capital, immediate installations, small & portable, versatile with tip attachment, no purging required					No capital, small & portable, ergonomically preferred	Repeatable shot size, no purging, versatile tip geometry	Precision shot size control, no purging, versatile tip geometry, improved bead termination
Operator Responsibility	Dispensed size, cycle-time, location & shape	Dispensed size, cycle-time, pressure, location & shape		Dispensed size, cycle-time, pressure, location & shape	Dispensed size, cycle-time, location & shape	Dispensed size, location & shape	Location & shape	Location & shape
Variability in Dispensed Part	Size, shape, rate & location			Size, shape, rate & location	Size, shape & location	Size, shape & location	Location & shape	Location & shape
Parker Chomerics Material Package Description	1.4 cc & 120 cc (1 pint with vial)	1-10 cc Syringe	10:1 35-250 cc 1:1 45-200 cc Cartridge with static mixer	300 cc Aluminum cartridge		30-360 cc Cartridge	30-360 cc Cartridge	30-360 cc Cartridge

When designing in a dispensable thermal interface material, there are several considerations to keep in mind when determining the appropriate product. The main purpose of the material is to conduct heat, but with a dispensable gel, there is more to the selection process than simply evaluating thermal conductivities. These tables show various considerations related to the volume of parts involved in an application.

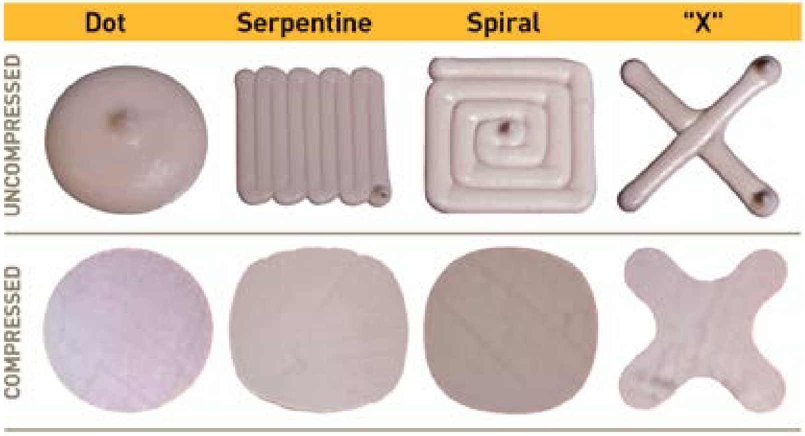
adapted from one job to another. Even with dispense equipment programming time built into the setup cost, the process can be cost-efficient compared to the time required to design and produce pad-application tooling and the additional effort to then qualify the application process.

- **Throughput** – Speed in part production is application-dependent, but to illustrate the potential advantage of gels we will cite a specific customer example. This particular customer was considering a switch from pads to gels and ran a test of both materials to gauge the difference in throughput. Their study revealed that it required an operator 18 seconds to apply one pad, including handling the pad, placing it properly and then moving on to the next component. Using a gel and an automated process, those same steps required only four seconds.

  The argument favoring gels grows even more convincing if there are multiple dispense locations on a single part. An automated/robotic gel dispenser can hit each of the locations in one cycle, whereas with a gap pad, the operator would have to apply a pad to each part individually.

- **Ease of application** – When placing a gap pad, the operator needs to know the pad's orientation. There's a top side and bottom side to the pad, and in many instances, there are left-right and/or up-down orientations. Manual application introduces more risk for human error. With gel application, the metered gel is simply dispensed onto a specific location.

- **Precision** – A benefit of the gap pad is that it can be cut to the exact shape of the customer part, whereas the gel takes the shape of how it spreads out once it is compressed. The specific application will drive the degree of precision required, as well as determine the acceptability of whether the gel material extends beyond the surface of what it is being applied to.



To maximize thermal performance, the thermal material must contact the entire target area on both the component and heat sink surfaces without air entrapment. In order to achieve this, a proper dispense pattern is critical. Taking part considerations into account, the next process design task is to specify the dispensed material pattern. A simple dot like the first pattern provides adequate coverage, shortest cycle time and least chance of introducing air into the thermal interface material. The more complex the profile, the greater the probability for introducing air (e.g., serpentine and spiral).

- **Shape complexity** *(see above)* – The shape a gel is dispensed into can help determine and control the ease of manufacturing and shape of the resulting spread. For instance, a dollop or "Hershey's kiss" type of shape is the simplest to dispense and will result in a roundish cross-section. An X-shape or serpentine dispense pattern results in a square cross-section at the expense of throughput. Very complex or thin shapes may not necessarily be well accommodated with die cut gap pads; a gel may be able to achieve those geometries better.

continued next page

- **Cost** – On a broad spectrum, gels tend to be less expensive on a volume basis when comparing them with a gap pad product of a similar performance level. Experience with multiple applications suggests that about 5,000 parts per year is the threshold where it becomes more economical to use gels and an automated dispensing system versus pads that are manually applied for the same application. Shape and geometry play heavily into that calculation however.

  Dispensing equipment investment can start at $10,000 to $30,000 for low-volume, tabletop units that require an operator. Increased sophistication and added features like camera recognition for quality control bring the equipment cost to $80,000 to $120,000 plus installation and training for a fully automated system.

- **Packaging –** Gel packaging starts in 10 cc cartridges, which are suitable for manual dispensing for use as samples or very low volume applications. The next tier up is a variety of pneumatic-dispensed cartridges ranging from 30 cc to 600 cc. Those require simple dispensing equipment, which typically includes a high-pressure air line with a regulator and nozzle to connect it to the cartridge. An operator can dispense it by hand or there could be some type of robot-assist mechanism.

  The largest packages, supporting the highest throughput volumes, are one- or five-gallon pails. These require a pneumatic pump to push the material into a secondary metering valve.

  Pad packaging is essentially as complex as the customer part is. A geometrically complex die-cut part pad has costs associated with developing and producing the pad to that shape. However, there are other options if a customer wants to handle cutting the pad on their own and/or has multiple shape requirements with a lower budget. For instance, pads are available in sheet form that can be readily cut or trimmed prior to application.

  Gel dispensing gives the customer more control, which is often an advantage. Customers can make changes on the fly without having to change a drawing, perform a first-article inspection, and complete formal engineering change control procedures involved in modifying the design of a part, for example.

Typical Gel packaging options range from small manual cartridges for sampling or testing to larger cartridges for pneumatic dispensing.

Typical high-volume packaging options

Conclusion

Gap filler pads have long been the go-to choice for many design engineers, but recent advances in thermal gels, which are highly conformable, pre-cured single-component compounds, can provide superior performance, a greater ease of manufacturing and assembly, and a lower cost in certain high-volume applications; particularly as electronic design applications get smaller, more fragile and more complex.

Maintaining an open mind to using high-performance gels is a consideration that could pay off in performance, manufacturing efficiency and cost savings.

Parker Chomerics is a division of Parker Hannifin Corporation, a Fortune 250 global leader in motion and control technologies, and is part of the Engineered Materials Group.

Parker Chomerics is the global leader in development and application of electrically and thermally conductive materials in electronics, transportation and alternative energy systems.

For more information, visit **www.parker.com/chomerics.**

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