WHITE PAPER

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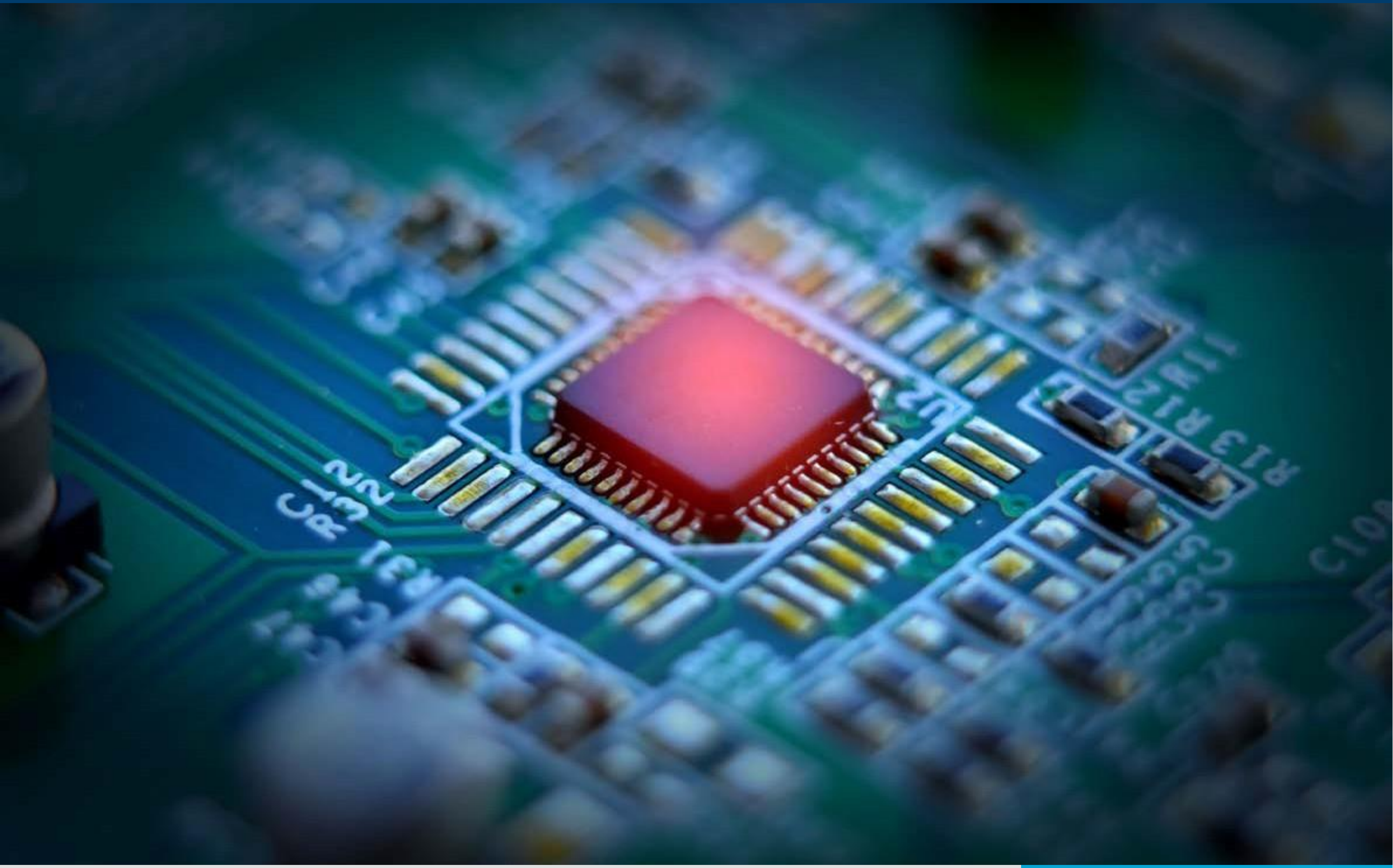

INNOVATIVE TECHNOLOGY

PRACTICAL TIPS

PROVEN PROCESSES

Stay cool – with perfectly dispensed thermally conductive materials

Electronic vehicles, devices and components must not overheat, otherwise they may fail to operate correctly. Thermal management is a major technical challenge as components are getting smaller, power densities are increasing and demands on robustness and reliability are becoming more stringent. To prevent power losses or defects resulting from overheating, liquid thermal interface materials (TIMs) are being increasingly used to dissipate their heat. This White Paper discusses the aspects that need to be taken into account when dispensing these mostly highly viscous, highly abrasive materials and why in many cases they are better alternatives to pads, tapes and foils.

Fig. 1: Thermal runaways are not only a significant safety risk, they may even ruin confidence in a product.

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Five key aspects of thermal management

1. Why does heat have to be removed from electronic components?

If you don't remove heat properly from electronic components, they will malfunction, fail or even catch fire. Malfunctioning components in vehicles or industrial plants generally lead to serious damage and high costs. In the event of a fire, for example due to a thermal runaway (overheating of a battery), the entire device, vehicle or plant is usually destroyed (Fig. 1).

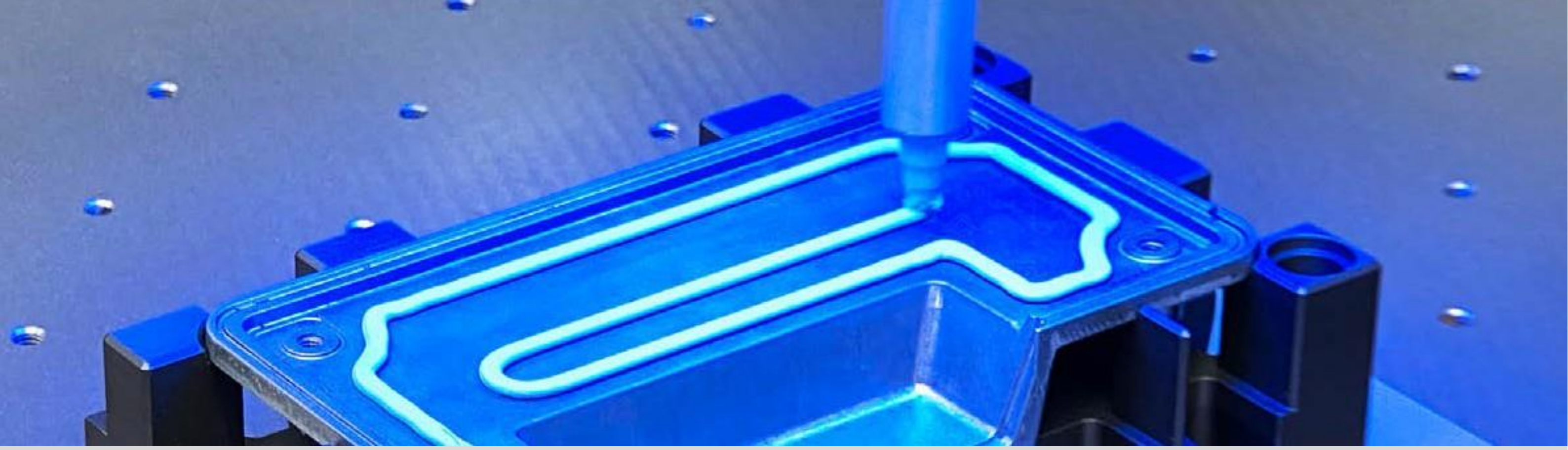
Practical tip: Based on the rule of thumb that a 10 °C rise in temperature will double the rate of a reaction, we can say that every 10 °C rise in the temperature of a component will double its failure rate.

2. Which electronic components require considerable thermal management?

The list is long – because the widespread and increasingly critical use of batteries, transformers, electric motors, power electronics, embedded systems, IoT, sensors, optoelectronics, light and so on is leading not only to more and more areas of application but also to greater demands on thermal management.

3. Which trends and developments are placing greater demands on thermal management?

More and more system-relevant electronic components are being used in contemporary sectors such as new mobility (including autonomous driving), the energy revolution, digitalization and the Internet of Things (IoT). This places increasing demands not only on performance but also on safety. At the same time, the trend toward component miniaturization is resulting in ever higher power densities with more and more heat being generated in the component. From a manufacturing perspective, small and complex component geometries, large production volumes, highly automated series production, short cycle times, highly abrasive TIMs, strict quality requirements and maximum cost-effectiveness are defining the framework demands that solutions have to meet.



4. Are solid or liquid materials preferred for thermal management?

This varies from component to component. However, there is a clear tendency to use liquid thermal materials. Gap fillers and heat-conducting adhesives play an important role here.

The reasons are as follows:

- Free contour design
- Compensation for different component heights
- Easier to apply, even in hard-to-reach places
- Greater thermal conductivity
- Additional functions in the material (e.g. adhesive effect)

5. What do I need to consider when specifying a thermal management solution?

In thermal management there are always various aspects that need to be weighed against one another (Fig. 2). It is crucial for system and material partners to have a wide range of technical solutions available as well as experience with the relevant components. It is important for the know-how of the system partner to be included at an early stage of the design process so that the component is developed from the very outset with a view to optimizing its thermal management.

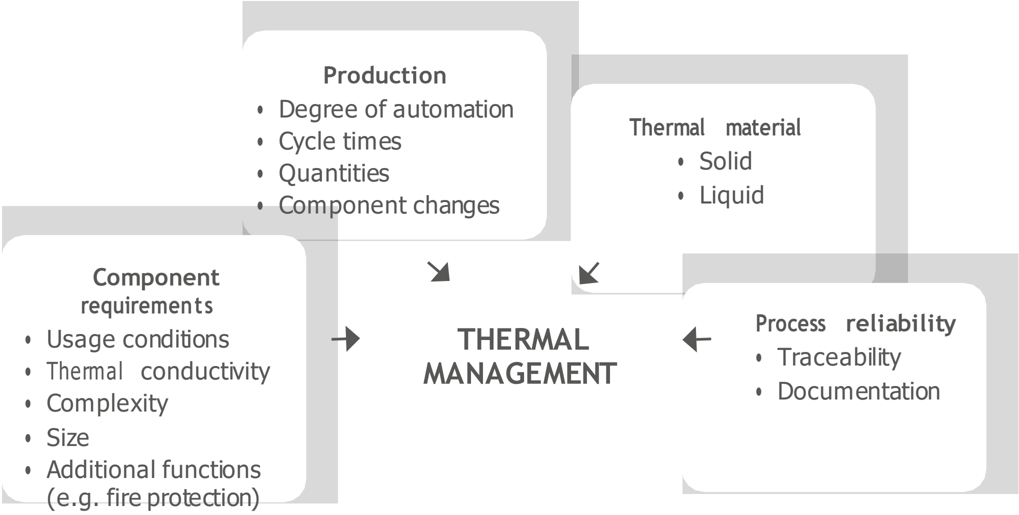


Fig. 2: Key factors for a thermal management solution.

Material types and their limitations

Many different TIM solutions are used for heat dissipation. They serve to bridge the air gap between the heat source and the heat sink – for example a circuit board and a cooling element – and to reliably remove the heat (Fig. 3). Different solutions have been developed to match the ever-wider variety of electronic components. It is therefore important to differentiate between the available materials.

Heat-conducting pads - Usually supplied prepunched, they are placed on the surface structures during the production process. They are usually between 0.25 and 5 mm thick. Their thermal conductivity varies between 1 and 20 W/(m·K). Pads are easy to handle for flat components or simple parallel, joining surfaces. For reliable thermal coupling, however, the connection between the component and the heat sink must be screwed or clamped.

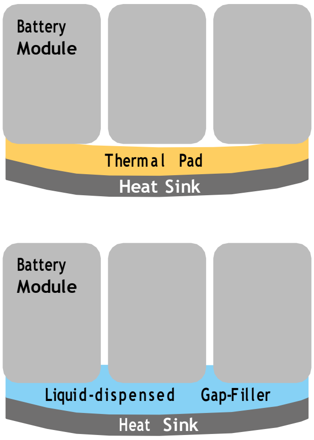


Fig. 3: In battery production, liquid gap fillers reliably close all the gaps.

Heat-conducting tapes and foils - These consist of a carrier matrix (such as polyimide film, fiber glass mat, copper or aluminum foil) to which pressure-sensitive adhesives are applied. The latter are enriched with heat-conducting fillers. Depending on the thickness of the tapes, good conformability with the joining partners can be achieved. They are easy to handle and do not require any additional mechanical fastening. However, they are not suitable for uneven and/or complex joining surfaces. The disadvantages here are the risk of damage during reworking and possible detachment at high temperatures.

Phase-change materials (PCMs) - These molded elements soften or liquefy when heat is applied to them (50 °C to 100 °C). This effect is used to fill small cavities, unevenness or hard-to-reach places on the surfaces of the joining partners. This improves surface contact and increases heat exchange. The disadvantage is that, like all molded parts, they require additional mechanical fastening. Post-processing is also difficult.

Soldering agents - These are melted at low temperature, filling the air gap between the joining partners. Their advantage is their high thermal conductivity. From a processing point of view, the risk of voids (cavities in a solder joint) and the high process complexity must be taken into account. Another problem is the possible risk of corrosion due to a potential difference between the solder and the base material.

Greases, gels - Thanks to their liquid to paste-like consistency, these materials are highly suitable for compensating for unevenness on the surfaces of the joining partners. Heat-conducting greases do not harden after they are applied to the component. Compared to other TIMs, they are only slightly thermally conductive. At high temperatures there is a risk that they will dry out. Pump-out effects also occur, in other words the greases can liquefy and escape after several warm-up and cool-down phases. Their advantages include their suitability for components with individual contours, their ability to be easily reworked without the risk of damage, and their comparatively low price. However, additional mechanical fastenings are needed here as well. 1C gels, which are mostly precured, have a similar property profile to that of thermally conductive greases. However, they have a lower propensity to pump-out effects.

Dispensable thermal pastes (gap fillers) - These highly abrasive paste materials, enriched with special fillers, are applied manually or automatically to a component and then cured. 1C and 2C materials are used, often on a silicone basis. However, developments here are in flux – in research projects such as the OWES project [1], materials with a thermal conductivity of 5 W/(m·K) have been produced, a value which today falls within the range of most requirements. For industrial series production, care must be taken to ensure that the pressure-sensitive battery is not damaged, that the fillers are evenly distributed, that bubble-free gap filling is ensured and that the cycle times and tolerances required in industry are achieved. Thanks to their better fit, gap-filler materials are suitable for components with complicated topographies, including those with multi-layer surfaces. Unlike pads, they can compensate for major unevenness and provide better heat dissipation. Sensitive electronic components are subjected to less stress when these gap fillers are applied. This reduces the risk of wastage. Gap-filler putties are a special form of gap fillers. These are extremely soft materials that can be compressed to more than 50% of their original thickness for improved heat transfer.

Practical tip: When it comes to applying heat-conducting pastes, the rule is as follows: as thin as possible, as thick as necessary. While a layer that is too thin makes proper contact difficult, applying too thick a heat-conducting medium can have an insulating effect.

Heat-conducting adhesives - These perform a dual function: thermal coupling and mechanical coupling. Their specific thermal conductivity is lower than that of gap fillers. In order to ensure reliable dual functionality, the quantity of filler must be precisely adapted to the carrier material because a high filler content to improve thermal conductivity will immediately result in a deterioration in the adhesive properties. Conversely, if the adhesive content is too low, there is a risk that the connection will begin to loosen under the influence of temperature.

Practical tip: If thermally conductive material cannot compensate for the stress between the components, there is a risk of cracks at the interface to the thermally conductive material and in the component, and therefore defects or damage due to insufficient heat dissipation.

Criteria for selecting gap fillers or heat-conducting adhesives

Coefficient of thermal conductivity λ

This is a key parameter (unit: W/(m·K)) for evaluating heat-conducting materials. It is also referred to as thermal conductivity or thermal conductance and indicates the ability of a substance to dissipate thermal energy. The greater the thermal conductivity, the greater the amount of heat transferred per unit of time.

Coefficient of thermal expansion α

This parameter for the components to be connected is also important. It indicates how the dimensions of a material will change in response to changes in temperature. If two materials with very different coefficients of thermal expansion are to be coupled, the gap filler or adhesive must be able to compensate for the different thermo-mechanical stresses between the component materials.

Fillers determine viscosity and abrasion

Gap fillers are formulated so they flow even at low pressures – for example when squeezed – and solidify after a short period of rest. They remain in shape after being applied to the component and can be cured. Their thermal conductivity is “adjusted” by adding fillers such as aluminum oxide, silver or boron nitride. These take the form of fragments, spheres or cubes and – depending on the type of filler, raw material quality and processing methods – often have high hardness

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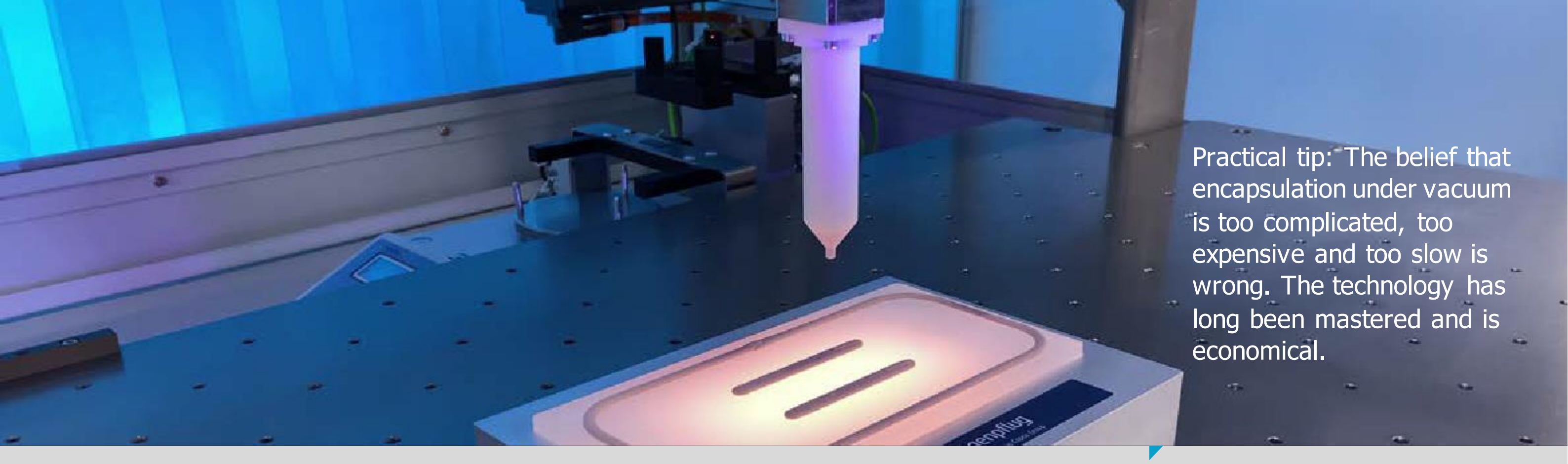
[1] https://www.ifam.fraunhofer.de/de/magazin/eine-neue-generation-von-gapfillern.html
or
https://www.ifam.fraunhofer.de/content/dam/ifam/de/documents/Klebtechnik_Oberflaechen/Klebtechnische_Fertigung/cover-story-OWES-fraunhofer-ifam.pdf



Practical tip: The belief that encapsulation under vacuum is too complicated, too expensive and too slow is wrong. The technology has long been mastered and is economical.

levels and sharp edges. This results in gap fillers with the highest viscosity and abrasiveness and must be taken into account when selecting the preparation, feeding and dispensing systems. If material abrasiveness is not taken into consideration users run the risk of high maintenance and repair costs.

1C or 2C materials?

Today, there is a lot to be said for 2C materials. Although 1C materials do not have to be mixed before being applied, the logistics are more complex compared to 2C systems. Depending on whether cross-linking is initiated by humidity, UV or temperature, different precautionary measures need to be taken to ensure that the material does not begin to cure before being used. This may require continuous cooling of the material and/or special storage of the containers. 2C materials usually achieve better material properties and better performance. Other benefits include lower VOC emissions and often shorter curing times.

Practical tip: Total cost-of-ownership analyses must always be carried out to evaluate the economic viability of a system – abrasive materials in particular can lead to high maintenance and repair costs.

Optimal dispensing of thermally conductive pastes

Most heat-conducting materials are now used in highly automated electronics production plants featuring fully automated systems. Various solutions for dissipating heat are now available depending on the specific production requirements, such as the degree of automation, type of container and process monitoring system. Figure 4 shows a system solution designed specifically for processing highly abrasive media. It consists of an A280 material handling system, the DosP DP2001 high-performance dispenser and DispensingCell DC803.

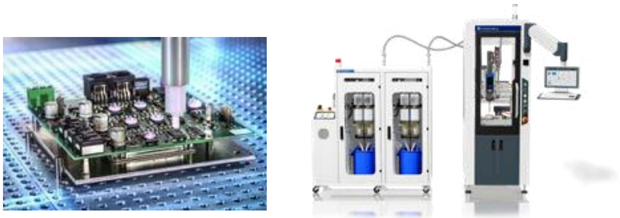


Fig. 4: Solution for processing highly abrasive media.

From a process point of view, gap fillers are applied in the same way as in other dispensing processes. In view of the materials to be processed, the following aspects need to be considered:

Material preparation - Preparation must be carefully matched to the fillers. The structure of the fillers must not be destroyed and the fillers must be evenly distributed in the material. There must be no bubbles in the material because air does not dissipate heat. Processing varies according to the gap filler used. Classic pastes do not need preparation as they are already supplied without air bubbles in the container. Gap fillers that are less paste-like should ideally be prepared and conveyed with a LiquiPrep LP804 (Fig. 5).

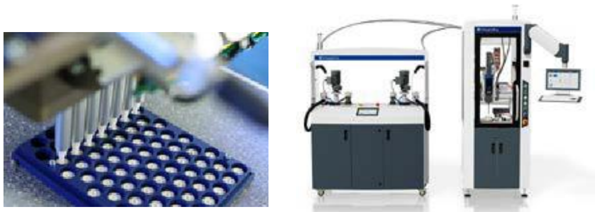
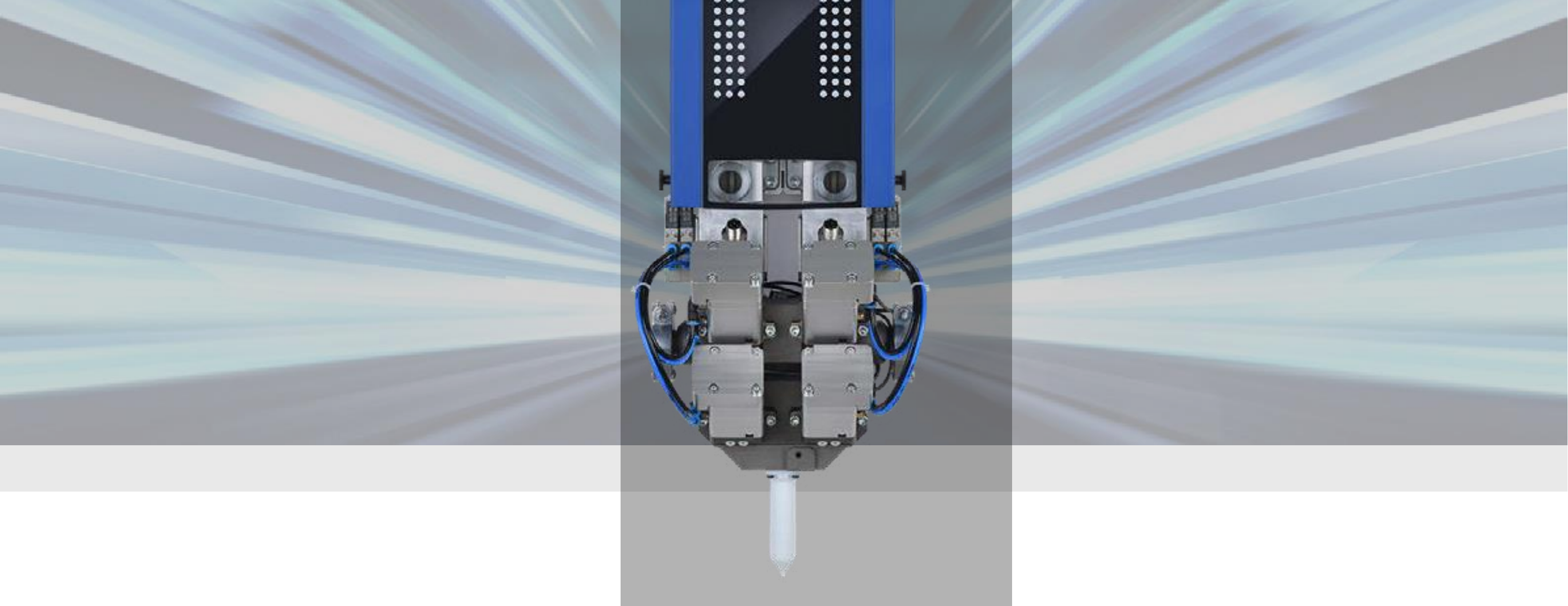


Fig. 5: Solution for less paste-like gap fillers.



Material feed - Depending on the material container, various systems are available for gently and reliably feeding high-viscosity thermally conductive media. For low material consumption, standard commercial cartridges with matching cartridge discharge systems are used. These ensure the material is fed uniformly to the dispensing system even at low volumes.

Reliable and robust feed systems are available for large standard containers such as hobbocks and pails. Follower plate systems (Fig. 6) have been used successfully in such cases. In these systems the air trapped between the plate and the surface of the material is drawn into the plate during docking. It then cannot enter the material or the feed process. Follower plate systems not only enable the container to be almost completely emptied, they also prevent dried media residue being transferred to the next material container. The plate is a disposable product and is discarded together with the empty pail at the end of the feed process.

Practical tip: If the size of the material cartridge means it needs to be connected to the dispenser via additional material lines, it may be a good idea to use a booster. The booster increases the feed pressure, thereby ensuring high dispensing speeds even with highly paste-like thermally conductive media.

Material dispensing - Because of their high viscosity and high proportion of abrasive fillers, thermally conductive materials place high demands on the dispensing systems. This step of the process often causes a bottleneck, particularly in fully automated production processes with short cycle times, and especially if the wrong technology is used for gap filler materials.

Piston dispensers have proven their worth for such dispensing tasks. Depending on the particular task, systems for small dispensing volumes (DosPL DPL2001) and fast cycle times (DosP DP2001) are available (Fig. 7+8). They operate on the principle of volumetric dispensing; in other words, the amount of material dispensed is determined by the geometry and the stroke of the cylinders. Since the amount of material is determined mechanically, the dispenser operates independently of temperature, feed pressure or material viscosity. When 2C media are used, the mixing ratio is kept constant by simultaneously discharging both cylinders into the shared mixing tube. For abrasive media, piston dispensers also offer long service life because they operate on the displacement principle and have no rotating elements. This avoids unnecessary wear on the parts carrying the media.

Fig. 6: A patented follower plate system ensures optimum emptying of containers.

Fig. 7: DosP DP2001 – optimized for highly liquid adhesives, sealants, potting materials and filled materials. It offers dispensing speeds up to 10 times faster – even for highly viscous materials.

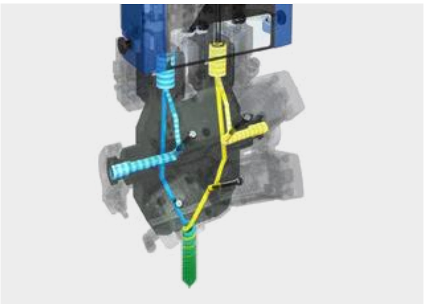


Fig. 8: The piston dispensing principle has proven successful for a wide variety of tasks.

Vacuum bonding - Vacuum bonding allows highly sensitive electronic components to be bonded without any mechanical stress or air pockets. The pressure pins used in conventional processes are not needed so the components are handled gently with no risk of damage or breakage.

Process and quality control - Maximum repeatability and dispensing quality are core project requirements. The RTVision.3d image processing system (Fig. 9), which can be integrated into a dispensing cell, checks and monitors the application of gap filler in real time. This reduces production time and ensures high, traceable product quality. With 100% inline inspection there is no increase in cycle times and no need for separate cells.

Fig. 9: Inspection and visualization are performed in real time as the adhesive or sealant is applied so the plant personnel know immediately whether this is "IO" or "NIO".

Integrated operating concept - UViS5 with its sensor-controlled pressure monitoring and valve status monitoring contributes to optimal dispensing quality during actual dispensing. Predefined functions as well as instant access to relevant process parameters ensure high efficiency and cost-effectiveness. What's more, the optional UPiC5 programming tool, which supplements and extends the UViS5 operator software (Fig. 10), enables complex dispensing programs to be quickly and conveniently created.

Fig. 10: UViS5 software – All the processes plus monitoring, maintenance and analysis tasks are always clearly in view.

(Pictures: Adobe Stock (p. 1, 2, 7), Scheugenpflug GmbH)

With high-tech solutions that are perfectly matched to one another it is possible to efficiently dispense abrasive gap fillers as well as thermally conductive adhesives – on complex geometries, in short cycle times and in large or small quantities. No matter what demands are made by a thermal management project, the tasks are performed reliably, economically and in the highest quality.

Would you like to know more about optimum dispensing of thermally conductive materials?

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