Thermal Materials for Packaging Power Electronics

Sanjay Misra

Henkel Adhesive Technologies, Chanhassen MN 55317

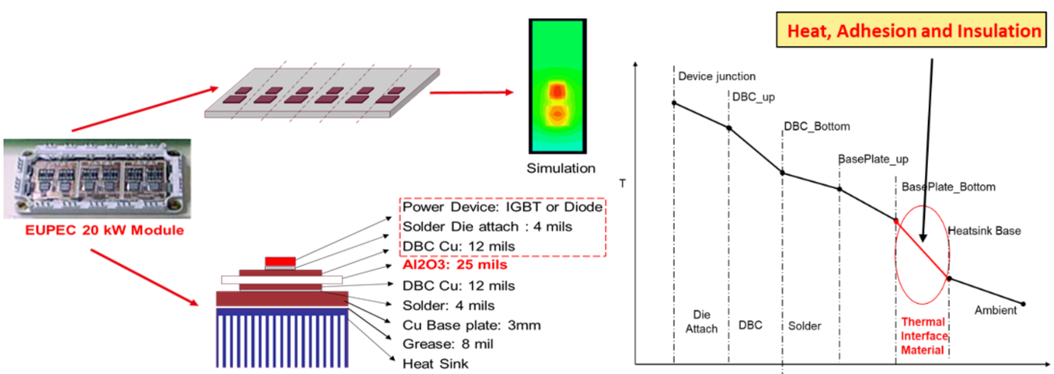
Introduction

Thermal management of power electronics, whether power supplies or power components, requires interfacing the package to a heat sink using a thermal interface material (TIM). Traditionally used thermal greases provide good end of line performance but they can degrade. Several alternatives and advances have now expanded that choice to a wide variety of product families. TIMs come in a wide variety of properties, physical formats and automation readiness to suit the wide variety of applications. Additionally, TIMs may be tasked with insulation reliability, adhesion, and encapsulation.

Typical Thermal Challenge

A typical thermal stack up has several resistances in series. The effective thermal bond line can be quite significant given the size and warpage of the assembly. The thermal resisatnce of the interface material can therefore a significant portion of the total. In many instances the end-of-line thermal resistance of the thermal interface can be 20-40% of the total junction to ambient. The thermal stack up includes materials of several different CTEs and goes through power and thermal cycling - leading to cyclic mechanical load on the interface. Therefore, the thermal interface material should be chosen carefully to balance and optimize lifetime thermal performance.[1-4]

For example, we show a typical IGBT thermal stack up. The thermal interface material is required to transfer heat during the lifetime of the product and therefore should be designed not only to flow and wet out the interface but also have stability in the interface.



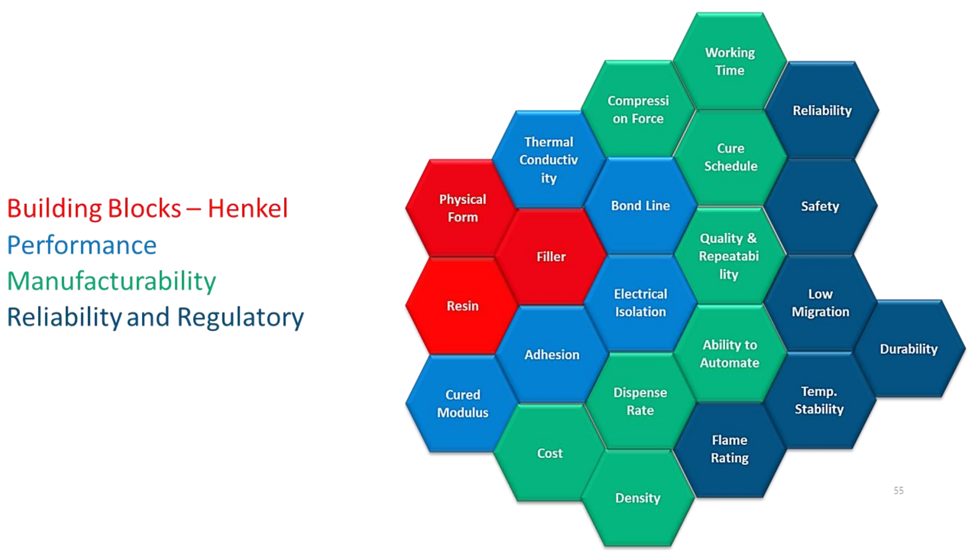
Thermal Interface Material Design

For thermal performance and long-term reliability, the TIM design needs to be optimized around three main criteria (1) Thermal conductivity of the TIM, (2) the rheology of the TIM, i.e. the deformation behavior of the material under stress and, (3) response to long term cycling. The interface between surfaces has gaps on two different length scales. The first is small-scale roughness typically O (1 μm) – from which air is eliminated by flow and wetting by the interface material. The second is related to larger gaps - O (100 -1000 μm) - due either to the non-planarity of surfaces and poor co-planarity. The thermal interface material needs to be able to conform to the surfaces, with a low external stress to produce deformation without straining the electronic components.

The thermal performance and rheology of thermal interface materials depend on both the polymer microstructure as well as the morphology and loading of the filler material. These properties are interdependent and cannot be manipulated in isolation. Since optimal performance depends on a combination of thermal conductivity and rheology one must match the application carefully to formulate the TIM. [5]

TIM manufacturers like Henkel can adjust formulations and processing to customize products to customer and market requirements. In general, when we think of TIM requirements, we can think of them in three categories:

1. **Performance**: These are must have properties for the TIM that are critical to the proper functioning of electronics. These include thermal impedance, insulation strength, adhesion, etc.
2. **Manufacturing**: These properties relate to how the end user will manufacture the power electronics assembly. These include dispensing, working time, automation, shelf life, costs, storage, etc.
3. **Reliability and Regulatory**: These characteristics are related to how the TIM performs typical environmental conditions for the final assembly and also whether certain safety and regulatory standards are met.



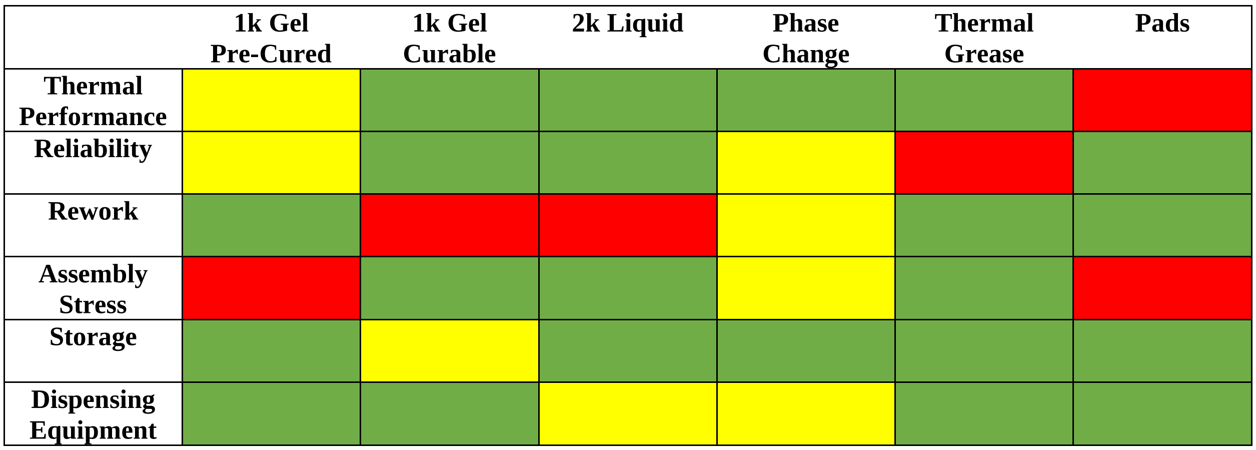
Application Performance
Thermal interface materials are available in several general categories:

Thermal Greases: These are relatively lower viscosity polymer liquids that have been loaded with thermally conductive particulates. These are thermoplastic, i.e. they will deform continuously under external stresses without limit. Greases can migrate or pump out at rates dependent on the viscosity. Thermal greases typically fall in the range of 1 – 5 W/m-K and typically cover bond lines from 50 – 150 microns. These can be dispensed or stenciled on to the heat sink or plate using typical liquid dispensing processes

Phase Change: These are materials generally solid at room temperature and melt at the phase change temperature. With film or fiberglass reinforcement they provide electrical insulation as well. They are easier to work with, can be automated and are generally better in terms of pump out resistance. In manufacturing, they may need to be over-torqued or re-torques after phase change. Like greases phase change products are available in the range of 1 – 5 W/m-K and thickness of 50 – 200 microns. They can be automated in label dispensing type application. Alternatively, they can be stenciled, or screen printed as well, above their melt point.

Pads: These are materials generally cross-linker polymeric material – typically reinforced with film or fiberglass to provide electrical insulation. They perform well under higher pressure and provide excellent reliability. These are typically used where high cut through resistance is required for insulation purposes. Commercially available pads range from 1 – 3 W/m-K and typically range from 150 – 250 microns in thickness.

Curable/Reactive Liquids: These may be either adhesives or form-in-place gap fillers and may be one component (1-k) or two components (2-k). These are thermoset materials that crosslink into a network that does not deform. These perform best – performance like grease but strong pump out resistance. The liquids can also be tailored to provide adhesion if needed. In addition, there is little mess and great opportunity for tailoring properties for automated manufacturing. These products come in a range of thermal conductivities – from 1 – 6 W/m-K and mainly dispensed through specialized equipment for highly filled thermal materials. These also offer the most attractive and flexible platform for high volume manufacturing, reduce inventory complexity and accommodate design changes easier.



Summary

Thermal interface materials come in a variety of formats and performance attributes – the selection depends on the thermal and electrical insulation needs. In addition, one must consider manufacturability and automation in choosing the right TIM.

References

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