Reliability and Performance of a Low Melt Alloy-based Thermal Interface System

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Introduction

Today's electronic components generate significant amounts of heat which must be removed to maintain their junction temperatures within safe operating limits. The heat removal process typically involves heat conduction between the electronic component and heat exchanger, or heat sink, via a thermal interface material. Small irregularities on both the component and heat sink surfaces prevent intimate contact and create air gaps that increase the resistance to the flow of heat. The thermal resistance of the interface between these two surfaces can be reduced by providing a highly wetting thermally conductive interface material which fills the air gaps and voids in the surfaces.

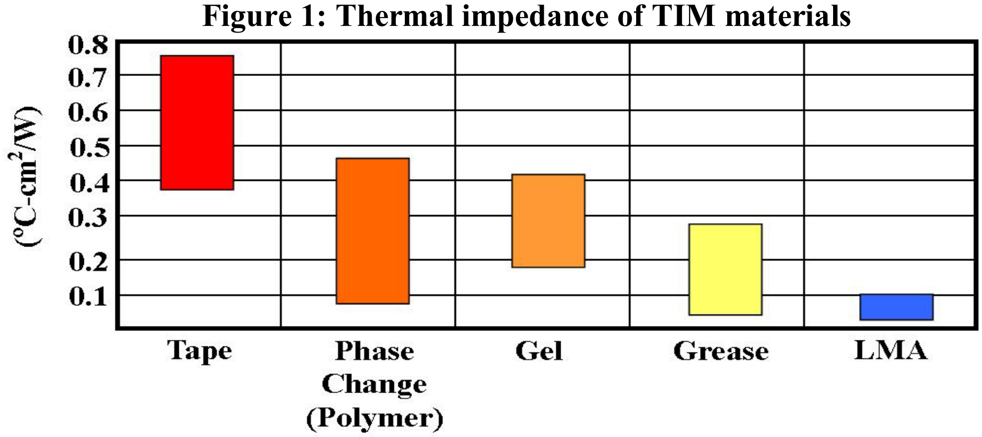
Although liquid or low melt alloy (LMA) based thermal interfaces offer both low interfacial resistance and high conductivity, earlier formulations have suffered from various reliability issues including: corrosion/oxidation, intermetallic formation, drip-out, dewetting, and migration. Unless mitigated, these mechanisms will continue to degrade the interface, causing excess heat buildup and resulting in a thermally related catastrophic failure of the actual electronic component.

Researchers at Enerdyne Solutions have created a Thermal Interface System combining a highly conductive heat spreader lid with a low melt alloy thermal interface material and proprietary modifiers to solve the limitations associated with LMA thermal interface materials. Material modifiers ensure stability and robustness even when subjected to high humidity, temperature cycling, shock and vibratory environments. The high conductivity lid not only provides excellent heat spreading, but also acts as a platform to support the LMA interface and modifying components.

Performance

Figure 1 [1] shows the evolution of common thermal interface (TIM) materials and the potential for LMAs to satisfy the continuously shrinking thermal budgets of the next generation of electronics components.

Figure 1: Thermal impedance of TIM materials



Liquid metals, such as alloys of bismuth, gallium and indium, potentially offer both low interfacial resistance and high conductivity. Several non-toxic alloys of gallium with very low melting points have also been identified as potential liquid metal interface materials. Thermal performance of such an interface would be more than one order of magnitude greater than many adhesives typically in use.

Reliability

Corrosion, considered to be the main failure mechanism in LMA materials, is primarily an electrochemical process in which surface atoms of the alloy react with a substance in contact with the exposed surface. Electricity passes from a negative region to a positive region (both on the LMA) through an electrolyte or corroding medium. In the typical electronics environment, the corroding medium is liquid or vapor phase moisture. Moisture films on a LMA may contain dissolved substances which affect corrosion: Oxygen, various oxides/dioxides, sulfates, chlorides and metal ions. The liquid phase of these alloys at operating temperatures facilitates rapid diffusion, accelerating the corrosion process.

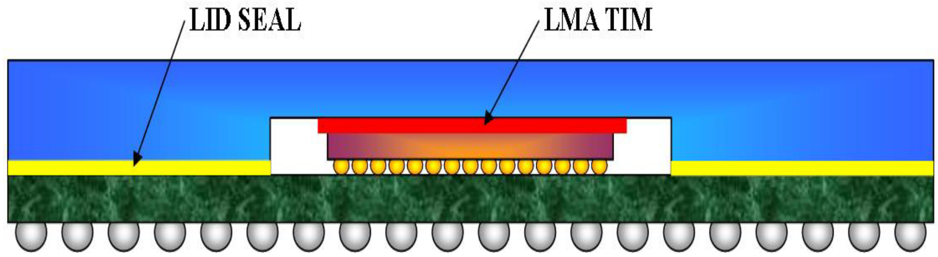


Figure 2: Flip Chip BGA package with heat spreader lid

Many current flip chip packages of the type depicted in Figure 2 do not contain a lid seal, but instead use a partial bead of adhesive to allow venting of the package cavity. The die underfill (between the chip and package laminate) provides all the moisture protection needed. However, to provide adequate LMA moisture protection, the package cavity must be closed to water vapor infiltration.

By providing an epoxy-based near-hermetic seal between the package lid and package laminate, corrosion due to moisture can be significantly reduced. For example, Indigo's moisture barrier system has successfully provided 750 hours of LMA protection in an 85 ^{0}C / 85% humidity environment.

Conclusions

LMA alloys as a thermal interface material offer superior thermal performance due to their high thermal conductivities and low contact resistance, resulting from excellent surface wetting. Reworkability, ease of handling, and no need for curing make this attractive in a high volume setting.

The various failure mechanisms which have plagued the past and present LMA products will be mitigated by applying a multidisciplinary approach to the challenge. A LMA system in beta release from Enerdyne promises to deliver LMA performance while providing a stable and robust product to satisfy the environmental and testing demands of the microelectronics industry.

Reference

[1] S. Lee, P. Chen, "Development of High Performance Thermal Interface Material", Intel Technology Symposium, Seattle, Washington, September 27-28, 2001.