APPLICATION NOTE
Liquid Metal Paste TIM Users' Guide

Introduction

Gallium-based liquid metals and now liquid metal pastes show a lot of promise as thermal interface materials due to their high thermal conductivity and ability to spread on most surfaces. Liquid metal paste is a reflow-free metal TIM with optimal wetting directly to Si, Cu, Ni, Au, and glass; it does not solidify at room temperature. No BSM is required. This material is RoHS compliant, non-toxic, and environmentally-friendly. Gallium-based liquid metal pastes are unique substances as they have a high density, high/medium/low viscosity depending on formulation and application, and very high surface tension. Because of these attributes, there are some unique challenges to using these materials effectively in thermal applications. Throughout this application note, some general recommendations will be given to ensure these materials are effectively applied and handled in a production environment.

Material Packaging and Storage

Gallium-based liquid metal pastes are very stable at, and should be stored at, room temperature. Liquid metal pastes are generally packaged in syringes (3, 5, 10, 30, and 55cc) or glass/plastic jars. Syringes should be stored tip down. Due to their corrosive nature, they should not be put in contact with most metals, including aluminum. Care should be taken not to use these materials on or in close proximity to aluminum surfaces. All shipments of gallium-based alloys are compliant with international shipping regulations. Indium Corporation's packaging of gallium-based alloys is certified UN-compliant, and all shipments comply with International Air Transport Association (IATA), DOT, and International Maritime Dangerous Goods (IMDG) regulations. These materials are pure metals, so there is no phase separation or other physical changes that would happen over time.

Application Recommendations

There are a couple ways gallium-based liquid metals can be applied to an interface for thermal applications. Following are general recommendations on the three most common uses:

1. Manual Brushing
2. Dispensing
3. Jetting

Before discussing specific use guidelines, it is important to discuss the physical properties of gallium-based liquid metal paste as these properties are critical to the effective use of the materials. Gallium-based liquid metal pastes have the highest surface tension of any liquid at room temperature. Based on that physical property, these metals should not be able to wet to or spread onto any surfaces—they should simply ball up. However, given the higher viscosity of liquid metal paste vs. liquid metal, they do actually spread isotopically onto most surfaces as seen in Figure 1(a) and 1(b). This happens due to the unique proprietary metal additive of the liquid metal paste. Depending on the amount of proprietary metal additive added to the liquid metal paste, the viscosity can be changed to allow the spread of the material over the surface isotopically.

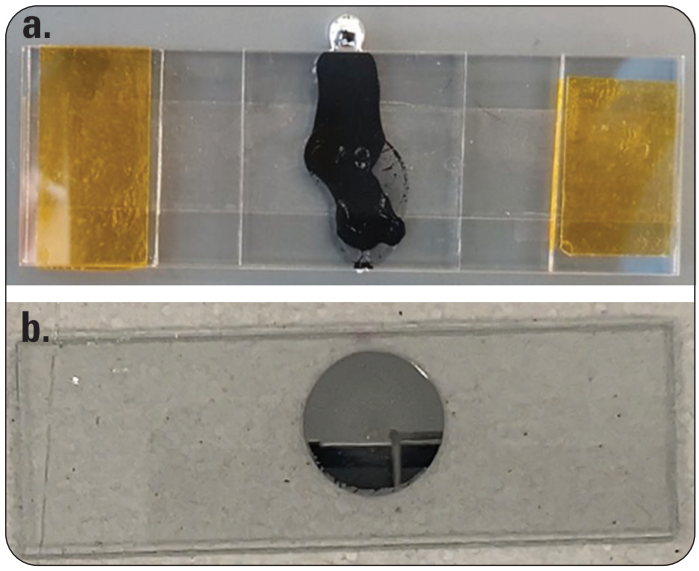

Figure 1. Viscosity of liquid metal (a) vs. liquid metal paste (b).

Even in an oxygen-free environment, this material will wet/spread. In addition, these materials have both high density and variable viscosity depending on application. By varying the viscosity, liquid metal pastes can be designed to be jetted or dispensed. These attributes will be discussed further in various application methods. Additionally, gallium-based liquid metal pastes are not compatible with aluminum. Lastly, gallium-based liquid metals are electrically conductive and will cause a short circuit if they come in contact with circuitry which is why we highly recommend the use of some kind of barrier when using these materials. Figure 2 shows an example of a barrier used with liquid metal paste.

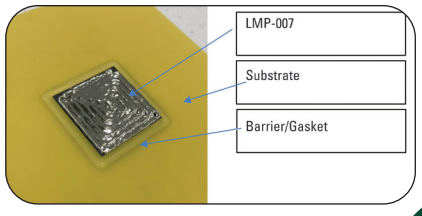

Figure 2. Jetted liquid metal paste (LMP-007) with UV curable barrier.

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Manual Brushing:

For prototypes and very low volume applications, it is very common to apply the liquid metal paste manually. In these cases, the liquid metal paste can be packaged in a syringe with a thumb plunger. The desired amount can be dispensed in a single dot on the back side of the chip or heat spreader. Using a scale to weigh out accurate deposits before and after spreading is highly recommended. The next step is to get the material to pin to the surfaces so there is a relatively thin and uniform layer across the entire surface that is to be cooled. The most effective way to achieve this result is to use a swab or brush, then rub the liquid metal paste back and forth across the surface. That motion will allow the material to sufficiently pin to the entire surface. The exact amount needed to cover a surface is dependent on the planarity of the two surfaces.

Jetting or Dispensing:

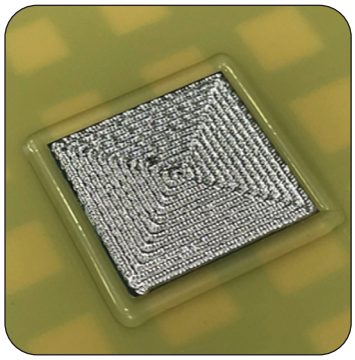

Figure 3. Filled rectangle jetting pattern.

A second application method is to use positive displacement dispensing equipment or liquid jetting equipment. Time pressure and some advanced dispensing systems can easily dispense this material with consistent bondline thickness and volume control. Figure 3 shows a rectangle filled by using a jetting pattern. Please reach out to Indium Corporation's thermal department before attempting to jet LMP. Figure 4 shows liquid metal paste patterns using advanced dispensing equipment.

Figure 4. Examples of liquid metal paste in a variety of dispense patterns.

When applying liquid metal paste by jetting or dispensing, a single large dot could be applied onto the silicon die or heat spreader. In Figure 1, you can see an example of what is likely to happen after applying a heat-sink to a large single dot of liquid metal paste. Because of its high density and variable viscosity, the material will spread isotopically over the chip surface. Figure 4 represents other preferred deposition patterns for dispensing and/or jetting, and the preferred pattern will be dependent on size and shape of the die. Depending on pattern chosen and specific die dimensions, a more uniform spread can be achieved when attaching the heat-sink. If using a jetting system, it is possible to jet dots so close together that the liquid metal paste will actually combine immediately after the jetting process. Figure 3 shows a chip that was jetted using this approach where the result is a single combined layer of liquid metal paste over the entire surface. Dispensing is the preferred method of depositing liquid metal paste. Again, please reach out to Indium Corporation's thermal department before attempting to jet LMP.

Barrier Material

There are hundreds of different barrier materials to choose from, but it's important to choose a barrier material that creates a hermetic seal. We have tested some UV curable materials made out of acrylated urethane and alkoxy silicone, some thermally curable materials made out of polydimethylsiloxane, and silicone rubber materials that require no curing. We recommend a double barrier. The first barrier should set your bondline and be higher than your die. This barrier could be right next to the die or up to 0.750mm off of the die edge. The second barrier can be any height that allows you to fully seal the package while ensuring the optimal bondline.

Pressure and Bondline Thickness Recommendation

Liquid metal paste only requires approximately 5–10psi in order to achieve optimal wetting. You can use higher pressure when using a barrier, but only if more force is required to fully compress the liquid metal paste over the entire substrate or die surface. This material is capable of achieving thin bondlines when spread manually, but as a general recommendation, we would say a minimum bondline thickness of 50µm and a maximum value of 500+µm. The unique properties of liquid metal and liquid metal paste is that the thermal resistance of this material does not increase rapidly with increased bondline thickness like other thermal interface materials.

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Cleaning, Handling, and Disposal

Gallium-based liquid metal pastes are generally low in toxicity, but gallium may be absorbed through the skin. Rubber or vinyl gloves should be worn at all times when handling gallium-containing alloys. Avoid eye and skin contact at all times. In the event of a spill, the gallium-containing alloys can be easily cleaned. Place some ice in a plastic bag, touch the spill with the bag of ice and hold in contact until the alloy freezes (solidifies). Scrape up the solidified alloy with a spatula and discard in accordance with local regulations. Alternatively, when solidifying the material is not possible, a simple soap and water mixture along with a lint-free rag can be used to remove the liquid metal paste from contact with unintended surfaces. Disposal of gallium-based alloys should be in accordance with all local regulations.

Liquid Metal Paste Application Comparison

	Deposition Method		
Variable	**Brushing**	**Jetting**	**Dispensing**
Accurate placement of material			
Consistent volume			
Minimal wastage			
Manufacturing speed (UPH)			
Minimal leakage during deposition			
Wetting of material onto bare silicon			

	Key
Good	
Acceptable	
Bad	

All of Indium Corporation's solder paste and preform manufacturing facilities are IATF 16949:2016 certified.
Indium Corporation is an ISO 9001:2015 registered company.

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