Low Melting Point Alloys: A Review

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***Abstract*- This paper describes the interfacial thermal performance of low melting alloys. Discussing about different types of Low Melting alloys, their characteristic properties which enable them to be used as thermal interface material. Their applications in different fields which make them far more versatile and effective in nature.**

Keywords— Low melting point, alloys, thermal, interface material

I. INTRODUCTION

New generations of electronic products squeeze more power and performance into even smaller packages, the relative importance of Thermal Management within the overall product design continues to increase [1]. An integral part of this thermal design process is the selection of the optimal Thermal Interface Material (or "TIM") for a specific product application.

Types of Thermal Interface Materials

•Thermal Pads/Insulators
•Thermally Conductive Adhesive Tapes
•Phase Change Materials
•Thermal Compounds or Greases
•Thermally Conductive Epoxy/Adhesives

Heat generated within a semiconductor component must be removed to the ambient environment to maintain the junction temperature of the component within safe operating limits. Often this heat removal process involves conduction from the component package surface to a heat sink or heat spreader that can more efficiently transfer the heat to the ambient environment [2]. This heat sink/ spreader has to be carefully joined to the package to minimize the thermal resistance of this newly formed thermal joint or interface.

Attaching a heat sink to a semiconductor package surface requires that two commercial grade surfaces be brought into intimate contact. Standard machined surfaces are rough and wavy, leading to relatively few actual contact points between the surfaces. When two such surfaces are joined, contact occurs only at the high points. The low points form air-filled gaps. Typical contact area can consist of more than 80 percent air voids, which creates a significant resistance to heat flow [3]. Thermal Interface Materials are used to eliminate these air gaps from the interface by conforming to the rough and uneven mating surfaces. Since Thermal Interface Materials have significantly greater thermal conductivity than the air they replace, the resistance across the interface decreases, and the component junction temperature will be reduced. In order to exploit both characteristics, most common heat tra nsfer materials,combine conductive particles with a liquid or p lastic. Examples of the former are greases and gels while the l atter include filled epoxies, silicones and acrylics [4].

II. CHARACTERISTIC PROPERTIES

There are a wide range of low melting alloys available. Yet some are restricted in their use based on their brittleness, toxicity, and reactive qualities [5]. Some of these elements are bismuth, gallium, tin, indium, zinc, cadmium, tellurium, antimony, thallium, mercury and lead. Many of these minerals may also be additives placed in during the formation of the low melting alloy [6].

The properties depend on the basis of the concentration of base metal. Few of the commonly used base metals are: -

A. Tin-Based:

Pewter is one common tin-based low melting alloy that is used. There will normally be a composition base where there will be about 50% tin element in the alloy. Manufacturers select tin due to its malleability when they require a metal that has a ductile characteristic, as it can be moulded and shaped without becoming brittle.

B. Bismuth-based:

Bismuth alloys will have a composition that is less of a ductile characteristic than tin, as it can become brittle [7]. Manufacturers use bismuth due to its expansion qualities when it melts and then solidifies as it can expand to up to 3.3%. The more bismuth is in an alloy, the more it expands. It is less expensive than other alloys that are featured and the least toxic as it can be used in applications where there is drinking water present.

C. Indium-based:

Indium alloys can be used when bonding onto gold, glass and ceramic surfaces as well as other materials. It can also weld onto itself and has the ability to wet surfaces that are non-metallic as well as metallic. When looking for a ductile element that offers fantastic fatigue resistance and a variety of low melting points, manufacturers may select indium alloys for their applications.

D. Gallium-based:

Due to its extremely low melting point, gallium-based alloys have the ability to melt when held in a person's hand. It changes into a liquid at room temperature, as manufacturers will often use it for thermal management applications [8]. It can also be used to wet on non-metallic and metallic surfaces including glass and porcelain. Like bismuth, gallium can become dense and brittle when solidifying.

E. Density Characteristics:

One of the main reasons for using low melting alloys is due to how it changes when it melts and then solidifies [9]. Some alloys are eutectic and will become pure liquid instantly, while others are Non-Eutectic and will transition through a semi-liquid state that has a type of slushy texture before becoming liquid [10]. Low melting alloys will also change in density when solidifying. Alloys such as bismuth and gallium will expand greatly when in their liquid state and then become dense when changing back into a solid [11].

Knowing the density of the alloy is important as the manufacturer needs to know how much it will shrink or expand [12]. If the metal shrinks too much, it may not create the proper bond with other materials, or have the required strength it needs to withstand stresses. If it expands too much, it can become brittle when changing back into a solid as the alloy might fail during the operation of the product or equipment.

Cerrobend, a popular low melting alloy, contains 50% bismuth, 26.7% lead, 13.3% tin, and 10% cadmium. The physical density at 20°C is 9.4 g/cm3. The 70°C (158°F) melting temperature of the alloy is substantially lower than the 300°C to 327°C (572°F to 620°F) melting temperature of the component metals. The low melting temperature of the alloy provides its greatest safety factor. Hazardous metallic oxide vapours that would be generated at the melting temperatures of the component metals are not generated at the 70°C (158°F) melting temperature of the alloy [13].

F. Desired properties:

Few of the desired properties of low melting point alloys are:

1. Suitable melting temperature
2. High melting enthalpy per volume unit [kJ/m³]
3. High specific heat [kJ/kg K]
4. Low volume changes due to the phase change
5. High thermal conductivity
6. Cycling stability
7. Nonflammable, nonpoisonous, non-corrosive

III. APPLICATIONS

A fusible alloy is essentially a type of metal alloy which can be fused with ease. These metal alloys can be melted at temperatures that are relatively low. They are typically eutectic alloys, meaning they have a sharp melting point [14]. Fusible alloys are often used as the term to describe alloys that have a melting point which is below 183 degrees Celsius.

Fusible alloys are irreplaceable in a range of applications where their low melting point is fundamental:

- Tube and profile bending
- Work holding of delicate or irregular pieces
- Fusible cores for plastic or composite moulding techniques
- Fusible plugs for boilers and pressure vessels
- Fusible safety devices for fire prevention such as sprinklers
- Lens blocking
- Rapid prototyping of press tools

Bend alloy is one of the most extensively used alloys in industry due to its primary characteristic of expansion on solidification from the molten state. This makes bend alloy an ideal material to support metal tubing with thin walls during bending operations. The alloy has a sharp melting point of 70 degrees Celsius and can consequently be melted with hot water [15].

The primary use of lens alloy is in grinding operations when it proves invaluable in holding glass or plastic lenses. WR 47 is best suited for plastic or composite lenses, whilst WR 58 is used primarily for glass. Due to its low melting properties, lens alloy is also a suitable component in the fuses of safety equipment [16]. Lens alloy can also be effective in proof casting.

Press alloy is considered close to eutectic having a relatively sharp melting point at 138°C. It has greater hardness and tensile strength than other fusible alloys and lends itself to anchoring, work-holding and low volume presswork [17]. WR 137 exhibits minimal expansion upon solidification from the molten state, this is useful for holding machined parts where shrinkage or expansion may deform the finished part [18].

Low melting alloys are considered fusible alloys because they melt at temperatures below 300 degrees are often combined with other metals in order to increase certain properties. For example, Bismuth is often combined with tin and/or silver to create lead-free solders that are non-toxic [19].

Low melting alloys can be combined with other metals in order to manufacture solder, certain types of fusible plugs, tube bending applications and coatings for other metals [20].

A. Solder

The most common application for low melting alloys is solder. In recent years, Bismuth and Indium have used in place of lead for metal solders due to the non-toxic properties of the metals [21]. Bismuth is typically used in hot welding applications while Indium is typically used for cold welding applications.

B. Safety Devices

Due to their melting points of less than 300 degrees, Gallium and Indium are often used in the manufacturing of safety devices for certain products, like fire suppression systems, boilers and water heaters [22]. These systems are designed to put out fires or stop explosions due to excessive heat and pressure. When temperatures increase beyond a certain threshold, the safety device melts. For sprinkler systems, the melting of the fusible plugs causes the sprinkler heads to activate. For boilers and water heaters, the release of the plug helps vent excess pressure.

C. Bonding Applications

Indium based alloys can be used for certain types of thermal bonding applications. Common materials often bonded with indium alloys include ceramic and glass as well as certain types of metals, including gold [23].

D. Coatings for Other Metals

Certain metals, like iron and steel, are extremely desirable due to their long lifespans and extreme durability. However, both of these metals are subject to corrosion, which causes rusting and structural deterioration [24]. In order to protect the underlying metal from corrosion, low melting alloys, like tin and gallium, can be combined with other metals to create corrosion resistant surface coating [25].

CONCLUSION

In this paper, discussed about the different types of low melting alloys, and how they are applied as thermal interface material by analyzing their characteristic properties. Also the different level of applications of Low Melting Alloys (LMA), thus enabling us to implement it in required places.

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