Process and Reliability Advantages of AuSn Eutectic Die-Attach

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Abstract

High-power semiconductor devices must be mounted using a robust die-attach material that can handle the temperature fluctuations generated by the chip and mechanical stresses due to CTE mismatches between the die material and the substrate it is mounted to. Traditionally, various die-attach products, such as metal-filled conductive epoxies, high lead-containing solders, and gold-silicon solders, have been sufficient to mount the chip and have it perform reliably for the life of the device it operates. However, the trend toward increasing heat generation, the demand for compact devices, the enactment of RoHS and REACH legislation, and the transition to GaAs chips, limit the use of conventional materials. The demand for high reliability in power devices, in light of these industry trends, has led engineers to evaluate various new materials for their die-attachment.

The use of a high temperature solder preform is proposed and demonstrated for use as a die-attach material in high power devices. The suggested solder preforms are eutectic gold-tin and may be implemented for high volume or lab quantity adoption using a Palomar Technologies' die bonder. This equipment is capable of handling the complete die-attach process, including high-accuracy pick-and-place of substrates, eutectic gold-tin preforms, and components; eutectic die-attach; and pulsed-heat reflow using a computer controlled Pulse Heat Stage (PHS). Each of these steps is precisely controlled to offer a near void-free eutectic die-attach between the device and its substrate. This is critical for thermal and electrical stability in high power applications. When the substrates, preforms, and components are supplied in high volume packaging, the assembly line can be fully automated, which enables a reduction in the cost of ownership and improves process yields.

Assembly applications suited for this process include, but are not limited to, high-brightness LEDs, power amplifiers, LASER diodes, VCSELS, lid attach, MEMS, RF packages, IGBT modules, and wafer scale packaging.

Keywords: AuSn solder, die bonder, solder preform, automated pick-and-place, eutectic die-attach, Pb-free, wafer scale packaging.

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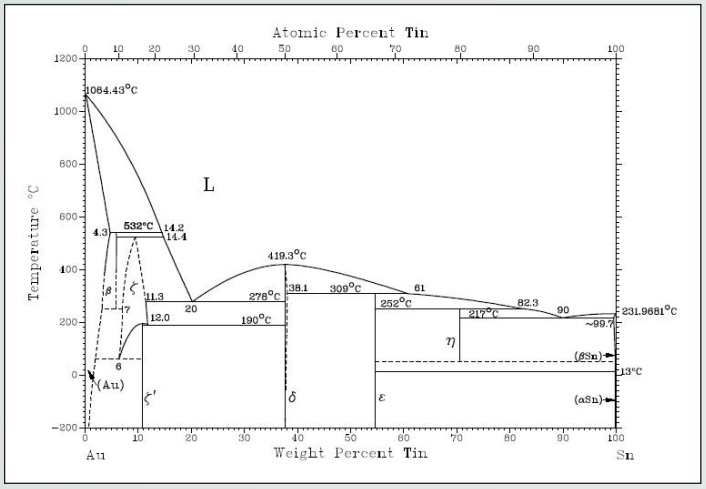
About Eutectic Die-Attach

The term eutectic comes from the Greek "*eutektos*," meaning "easily melted."

A eutectic solder mixture, such as the commonly used 80/20 ratio of gold and tin (AuSn), is a mixture of the two materials in such a specific ratio that they crystallize simultaneously at a lower temperature than the melting temperatures of the individual materials. This is referred to as a eutectic reaction. The temperature at which it takes place is called the eutectic temperature (280°C) and the combination of the composition (80/20) and temperature at which it takes place is called the eutectic point.



The eutectic die-attach process is well-established having been used in the first transistors and integrated circuits. Currently, eutectic die-attach has regained importance in the field of packaging optoelectronic components, MEMS and high-power communication devices.

Advances in material manufacturing and bonding methods have extended the range of applications for AuSn solder, especially for applications where lead is no longer an option due to legislation designed to reduce and eventually eliminate the use of poisonous lead in electronics and electronic waste.

The Impact of Lead-Free RoHS Legislation

The Restriction of Hazardous Substances Directive or RoHS was adopted in February 2003 by the European Union. The RoHS directive took effect on 1 July 2006, and is required to be enforced and become law in each member state. This directive restricts the use of six hazardous materials in the manufacture of various types of electronic and electrical equipment, including lead (Pb).

Advantages of AuSn

For most applications, AuSn is the most viable Pb-free power die-attach solder available. It fits into the required die-attach assembly processing temperatures; has the required mechanical strength, high electrical, and thermal conductivity; can be used with existing processing equipment; and comes with other reliability advantages and potential applications because it can be processed without a flux.

AuSn is robust and will survive the high operating temperatures inherent in applications, such as high power device operation, which may include subsequent process temperature cycles as the package is soldered to a next-level assembly, such as a circuit board or heat sink.

Power semiconductor devices such as rectifiers, power transistors, amplifiers, voltage regulators, and countless other automotive and consumer packages have become more thermally demanding. AuSn effectively dissipates the heat they produce.

While eutectic gold solders carry a higher material cost than some other die-attach materials, the reliability benefits they provide often justify this choice. In addition, process equipment for AuSn die-attach has made significant advances, allowing for higher throughput, more precise pick and place, lower voiding, and more controlled reflow temperatures.

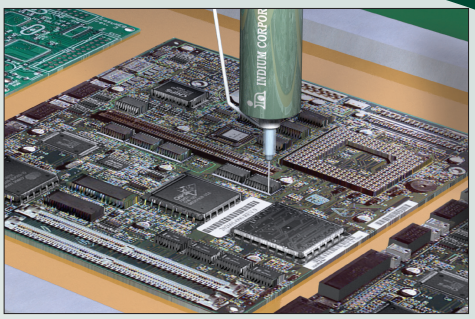
New manufacturing techniques allow for eutectic solder pastes, spheres, preforms, and wire to be made in a wider variety of forms and with more precision than soft lead-containing solders.

Gold Eutectic Alloys

Alloy Properties	Au/20Sn	Au/12Ge	Au/3.2Si
Solidus Temperature (°C)	280	356	363
Liquidus Temperature (°C)	280	356	363
Thermal Conductivity (W/mK)	57	44	27
Tensile Strength (PSI)	40000	26835	36975
Shear Strength (PSI)	40000	26825	31900
Thermal Expansion Coefficient (ppm/°C)	16	13	12

Solder Preforms.

Solder Spheres.



Solder Paste.

The following applications have benefited from the implementation of AuSn as their die-attach material versus other options:

AuSn Application 1:
Power Semiconductor Die-Attach

During the die-attach assembly process for a high power device, the die, with backside metallization, typically gold, is soldered to a metalized ceramic substrate, metal core package, or metal leadframe, which acts as a heat spreader.

AuSn solder is an ideal material choice for this attachment because it is able to perform the numerous functions required by this application, while withstanding extreme environmental operating conditions.

Required die-attach material characteristics:

- Mechanical strength under normal operating temperatures, which exceed 150°C
- Process temperature low enough that it will not affect the die functionality
- Thermomechanical fatigue resistance due to the shear loading stress from CTE mismatch between the die and package/leadframe
- High electrical conductivity
- High thermal conductivity to dissipate heat from the die to the leadframe
- Chemical inertness with low outgassing
- Ability to automate the attachment process
- Higher solidus temperature than subsequent solder reflow temperatures, as the package may be soldered to a circuit board

AuSn Application 2:
Advanced 3G and 4G RF Wireless

High-power amplifiers (10W – 200W) have traditionally been assembled using the gold-silicon (AuSi) eutectic system, which requires a higher bonding temperature (370°C). Some RF wireless amplifier applications have adopted lower cost packages with plastic content, which cannot handle the high temperatures of the AuSi process. Gold-tin (AuSn) is a lower temperature eutectic system with a reflow temperature of 280°C, a better suited reflow temperature with only a small process change.

AuSn Application 3:
III-V Semiconductors

Gallium arsenide (GaAs) applications, and InGaN and other III-V semiconductor applications requiring a high reliability soldered connection, also benefit from AuSn eutectic solders' lower process temperature, which is desirable from a performance standpoint.

Some III-V RF amplifier systems use significantly less power, generate less heat, and therefore require less power to cool the circuits making them a GREEN technology.

AuSn Application 4:
Micron Level MEMS Packaging Using AuSn solder

The excellent thermal properties, mechanical strength and relatively low melting temperature of gold-tin (AuSn) make it an attractive choice for high reliability bonding and hermetic sealing of MEMS devices.

In the quest to improve packaging scale and cost, wafer level packaging has become a critical technique in manufacturing MEMS devices on a commercial scale.

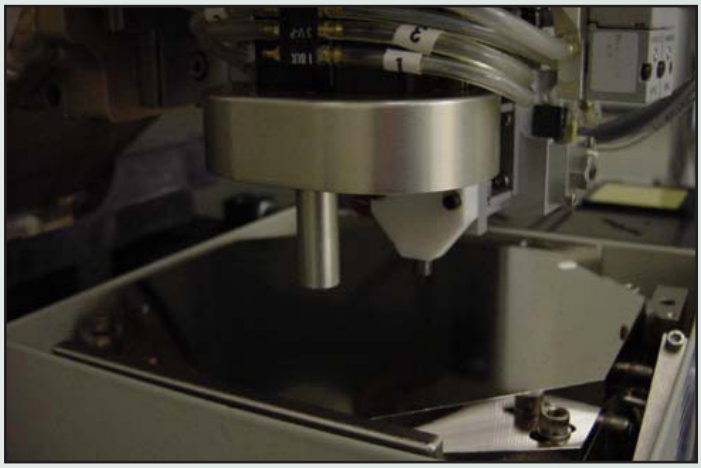
Typical Specifications for solder preforms and spheres:		
Preforms:	**Minimum size:**	150 microns diameter or square
	Dimensional tolerance:	150 microns to 1500 microns ± 25 microns >1500 microns ± 50 microns
	Thickness tolerance:	12.5 microns to 50 microns ± 5 microns 50 microns to 0.254mm ± 10 microns 0.254mm to 0.5mm ± 25 microns
Spheres:	**Minimum diameter:**	75 microns ± 12.5 microns

Table 1. Typical specifications for solder preforms and spheres.

Post-bond precision of +/- 1.5 microns, 3 sigma can be achieved in a high volume manufacturing process using Palomar Technologies Model 6500 die bonder.

Conclusions

AuSn solder is an excellent option when considering die-attach materials for applications requiring high-strength, high-temperature stability, precision placement, clean materials, and ease of use. Advances in packaging equipment have increased the throughput on this bonding, making it a much more commercially viable solution for applications ranging from small volume MEMS assemblies to high volume wireless RF packaging.



Palomar Technologies Model 6500 WSP features a heated wafer stage and heated bonding tool.

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