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Automatic Eutectic Die Attach

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Introduction

Automatic eutectic attachment is a leading technique for high-performance and high-capacity die attach applications. The needs of the current industry environment, with high volume and high placement accuracy of up to ±5 microns, call for flexible automated equipment that is swift, precise, and repeatable.

The unique thermal conductivity of eutectic bonding makes it more desirable than silver filled epoxy bonding in power devices or radio frequency amplifier applications.

When using eutectic bonding, the die is fixed immediately after the collet separates so there is no need to transfer the die to a curing oven to cement the bonds. Eutectic bonding's circumvention of silver filled epoxy's curing operation makes the process immune to die migration and saves an extra step in the die attach process.

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How Eutectic Die Attach Works

A eutectic system is a homogeneous mixture of substances that melts then solidifies, at a single temperature that is lower than the melting point of any of the constituents. During eutectic die attach, the substrate is first heated to a temperature just below the solder's eutectic temperature. As the temperature rises and the solder liquefies, the composition of the mixture changes, raising its melting point, thereby creating a solid bond between the components. The addition of scrubbing, or cyclical XY moves with applied force, pushes around the solder while it is liquid to create a void free bond between the die and bonding surface.

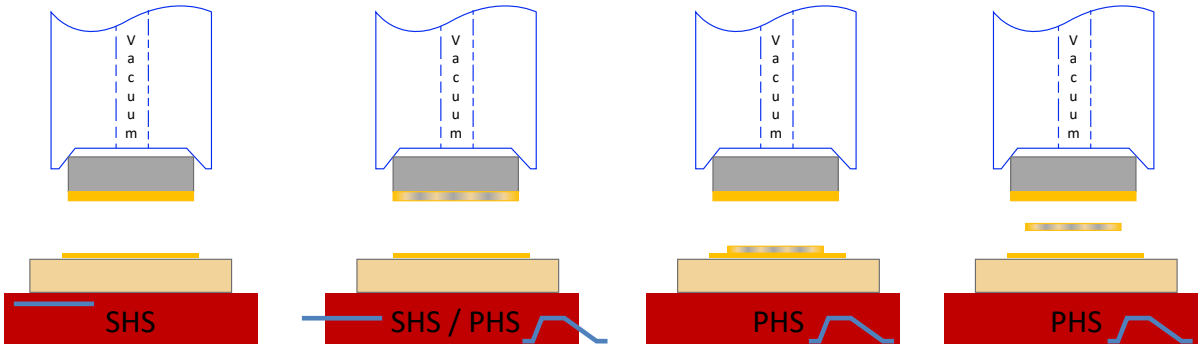
Eutectic bonding functions by using heat to melt the solder and cover gas to ensure a secure bond forms. Cover gas is used in the form of a passive component (such as 95 percent nitrogen) to prevent metal oxides from forming, and an active component (such as 5 percent hydrogen) to break away existing metal oxides. These factors work in conjunction with one another to create a bond that is electrically, thermally, and structurally sound.

Steady State vs Pulsed Heat Eutectic Die Attach

Eutectic die attach can be performed using two different configurations: **A Steady Heater Stage (SHS), which maintains one temperature or A Pulsed Heat Stage (PHS) which can produce a temperature profile.** The choice between the two techniques hinges on the desired process of die bonding.

The **Steady Heater Stage** can be used to bond an Au backside metalized Si die and an Au metalized substrate. The AuSi bond is formed between the two substrates when a steady amount of heat is applied to the die and substrate. In addition, the technique of scrubbing, or moving the die quickly over the substrate repeatedly on its XY axis in a "scrubbing" motion is used to strengthen the bond by removing voids.

The **Pulsed Heat Stage** is used in configurations such as when AuSn solder is pre-deposited on the die, the substrate, or sandwiched between the two. The solder is heated up precisely when the die and the substrate are in contact and bonding. If a Steady Heat Stage is used in this configuration, the AuSn can melt and change composition before the die is placed.



AuSi	AuSn on Die	AuSn on Substrate	AuSn Preform
Die w/Au flash	Die w/2-3um AuSn	Die w/2um Au	Die w/2-3um Au
Substrate w/Au	Substrate w/Au	Substrate w/AuSn	Substrate w/Au
Steady Heater Stage	Steady Heater Stage or Pulsed Heat Stage	Pulsed Heat Stage	Steady Heater Stage or Pulsed Heat Stage
Scrub X or Y or both	Scrub X or Y or both or none for small die	Scrub X or Y or both or none for small die	Scrub X or Y both or none for small die
2 Side or 4 Side Tool	2 Side, 4 Side, or Flat Tool if no scrub	2 Side, 4 Side, or Flat Tool of no scrub	2 Side, 4 Side, or Flat Tool if no scrub
1 PNP	1 PNP	1 PNP	2 PNP

Figure 1 Depending on the application, PHS or SHS techniques can be used to bond.

Wetting and Preform Solder Techniques

In the bond cycle, incremental thermal energy is supplied to the solder layer to promote the solder melting process. Liquefied solder then penetrates both bonding surfaces. An intermetallic bond develops, which is also known as wetting.

The solder, usually precipitated to the die foundation (backside metallization) or to the substrate, can also be supplied as preform - solder pieces cut to a certain percentage of the die size. While preforms are a cheap solution to apply solder, their use does require an additional pick-and-place process step.

In addition, for multi-chip module or packages with higher component density, solder paste offers ease of processing advantages as solder can be applied quickly to tack in place all the components. This is generally done via time-pressure or auger dispense and requires only one reflow cycle to finalize and secure the bonds.

Figure 2 Shiny Solder Wetting

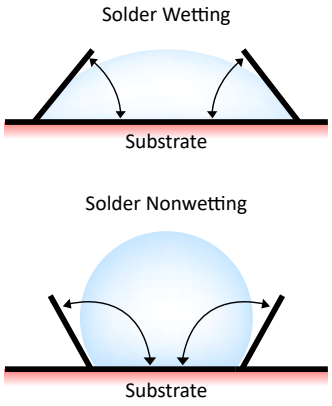


Figure 3
Solder Wetting vs Nonwetting

Automation for Increased Efficiency

The goal of automation is cost-effectiveness, given that a manual process has a very low capacity and requires a highly skilled operator. Because of longer cycle times per placement inherent in manual processes, the capability to perform multiple placements in a single pass to the heated work area is quite limited. State of the art assembly automation, wherever effectively applied, has resulted in tremendous cost savings and renewed competitiveness.

Present-day automatic die-bonding equipment permit multichip eutectic die attach packages to be processed and assembled in a single pass with a mechanized substrate and die handling. This means higher efficiency is achieved using an automatic die attach process compared to a manual die attach process.

The increase in speed and accuracy does come with a few qualifications. Customers looking to automate their die attach process must be aware that automated assembly has more stringent requirements when compared to manual assembly.

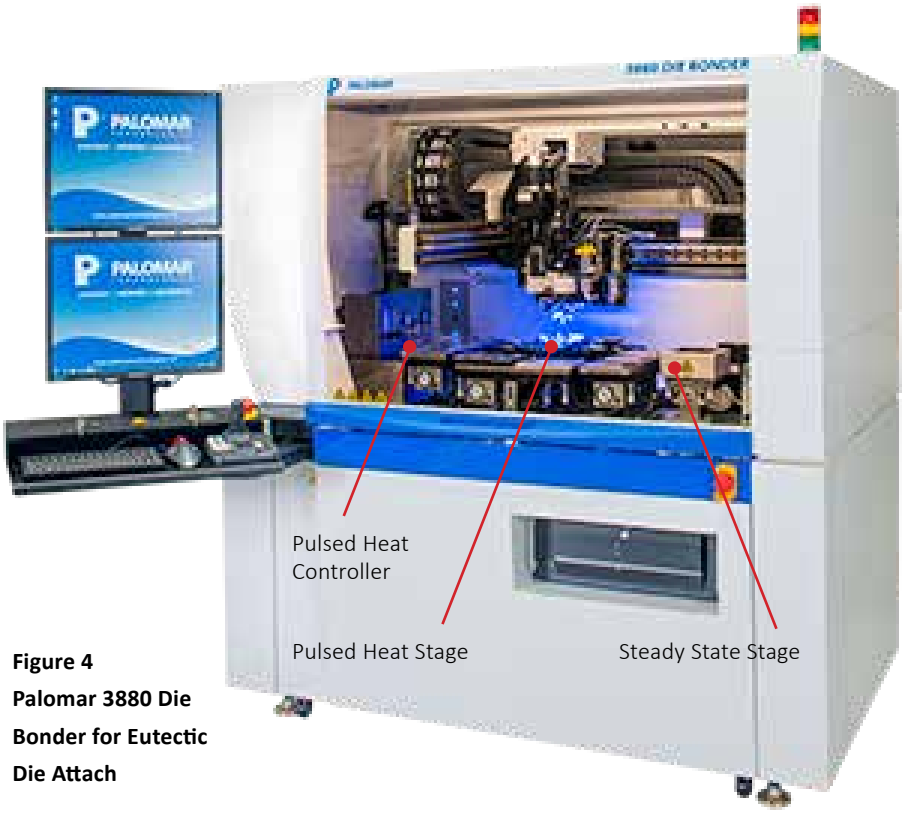


Figure 4
Palomar 3880 Die Bonder for Eutectic Die Attach

Automation Requirements

Although every application has its own set of requirements for automated eutectic die attach, some machine parameters are more critical than others. Critical control parameters include head force, soldering time, background temperature and incremented thermal energy, and cover gas flow.

Head force

Immediately after placing a die on the substrate, the bond head pushes down on the die with a specified force. The amount of force applied must be sufficient to stimulate solder reflow and hold the die in place during reflow. A precise and tightly regulated amount of head force must be used in order to avoid damaging the die.

Soldering time

The time of head force and incremental thermal energy largely determines the extent of solder reflow and impacts throughput time. Actual soldering time varies from a couple of seconds to a dozen seconds, depending on die size.

Background temperature and incremental thermal energy

Background temperature indirectly controls soldering time. The substrate is heated to a background temperature, which is increased during bonding until reflowing occurs. The background temperature determines the amount of incremental thermal energy needed to initiate the solder reflow.

Cover gas

The flow of cover gas affects the rate at which the solder reflows and determines the quality of the inter-metallic bond. This is done by creating an inert bonding environment to avoid oxidation. In addition, forming gas with an active component such as hydrogen, can be used to break away existing metal oxides. As the process of bonding takes place, it is critical to contain the chemically inactive environment to the work cell, as oxygen present in the air can degrade the bond; this also helps keep the process cost to a minimum.

Meeting Quality and Accuracy Demands

Several eutectic die attach methods can be used to successfully meet quality and accuracy demands. If the bonding platform allows for scrubbing, the addition of thermal energy can be easily controlled. Scrubbing translates load force into frictional heat by cyclically moving the die back and forth and/or left to right while exerting head force. This movement of the die also stimulates the solder which significantly reduces voiding between the die and bonding surface, creating a more thermally and structurally sound connection.

If the work cell offers flexibility to interact with third-party devices, a temperature controller with a low mass heat conductive strip can also be used to provide the additional heat needed to achieve quality solder reflow.

With the more pronounced demands for accuracy, close attention must be paid to mechanical imperfections. A vision system such as Palomar's VisionPilot®, is valuable for automatically inspecting proper placement on completed parts and storing placement accuracy data.

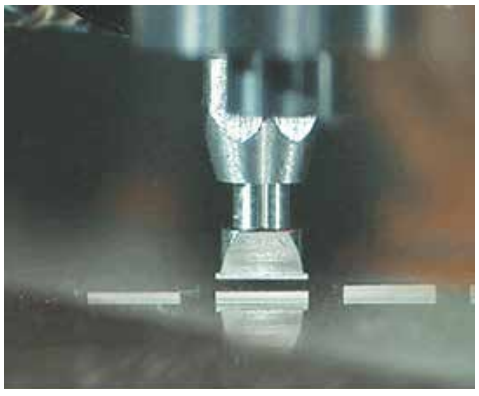


Figure 5 Scrub Tool

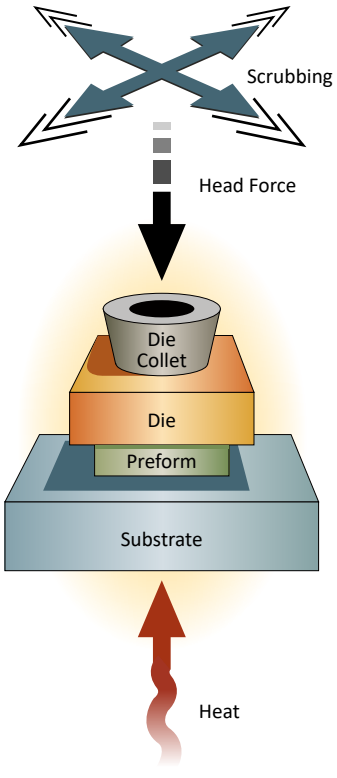


Figure 6 Scrubbing Process

Application Example

Let's look at a typical example of an application using eutectic die attach. In this example we are placing an exceptionally narrow die (20 × 200 mils) for a microwave application, Figure 7.

The placement accuracy is relatively forgiving (±1 mil) to allow constant wire bond length for tuning purposes, but the specific die shape makes even this requirement challenging to maintain. In this case, to avoid offset during placement, the perfect horizontal flatness of the eutectic die collet is essential; specially designed eutectic die collets are also necessary in order to prevent unwanted movement and damage to components.

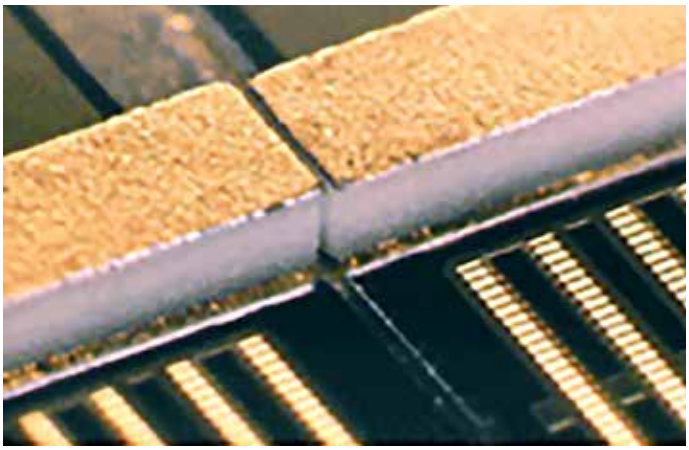


Figure 7 Eutectic Microwave Application

To maintain the tightly controlled solder precipitation at the foundation of the die, it is critical to have precise control over scrubbing. This requires a bonding platform that allows full control over the speed, distance, and axes on which this action occurs; each of these parameters play a vital role in the formation of a good eutectic bond.

Palomar Technologies Pulsed Heat Stage

Palomar Technologies' Pulsed Heat Stage (PHS), Figure 8, is an intuitive system for void-free eutectic die attach. Designed to improve on the Heat Stage techniques of other systems, PHS features four crucial advancements:

1. Controller
2. Data storage
3. Heater stage size
4. Programmable cover

Figure 8 Palomar 3880 Die Bonder PHS Option

Controller

Unlike other systems which require manual interaction in the form of dials, Palomar Technologies' PHS, Figure 9, is a highly accurate computer controlled solution. The PHS software enables users to create a tightly regulated and software-programmed ramp up/ramp down with multiple peak points through a sophisticated control algorithm, resulting in more complex heat profiles. The computer-generated display provides both real-time monitoring and a retroactive look at the heat up and cool down process. Having programmable software also eliminates the need for extra attention from operators, as once the desired temperature profiles are set, the PHS follows the direction from the inputted computer settings.

Figure 9 Palomar 3880 Die Bonder PHS Option

Data Storage

Data storage for traceability has become a high priority for many medical and defense applications using eutectic die attach. Since other manual systems do not have computer communication, actual performance data cannot be stored. Palomar Technologies' PHS offers a complete data storage repository to meet process parameters for organizations with strict reporting needs.

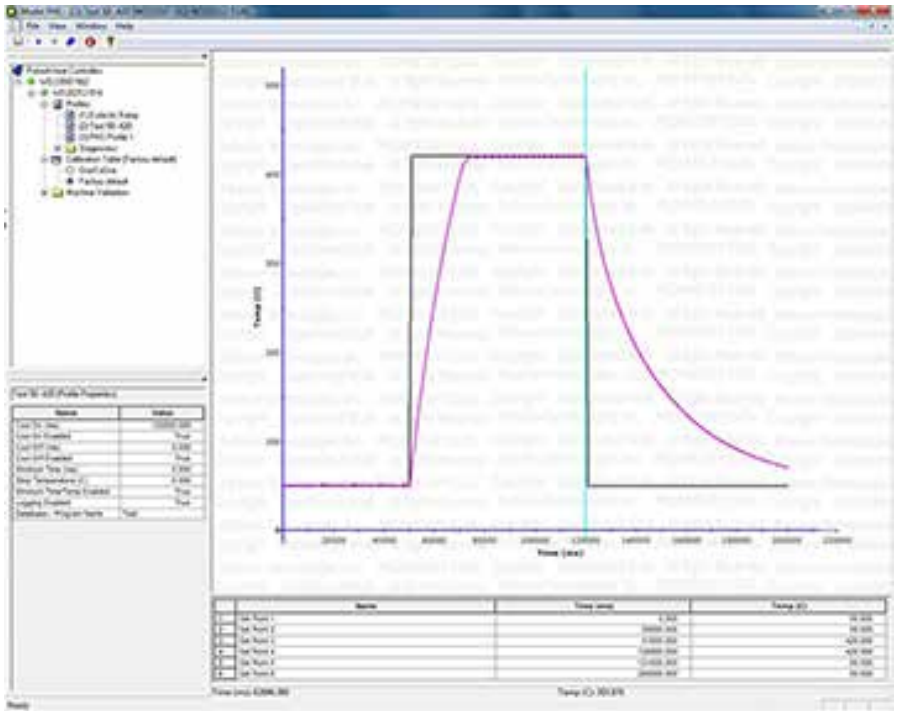


Figure 10 Palomar Pulse Heat Stage Software

Heater Stage Size

Unlike the single-stage size available in many of the eutectic systems, Palomar Technologies' PHS offers two-stage sizes, Figures 11 and 12. Adding a second—and smaller—stage size offers the flexibility to cut the amount of time needed for the eutectic die bonding process. Simply put, a smaller stage reduces the thermal mass, resulting in quicker temperature ramp up and cooling of the stage and its respective heated parts. The PHS offers a leveling capability, equipped with highly accurate micrometer dials.

Figure 11 Palomar 20x48mm PHS Stage and Controller

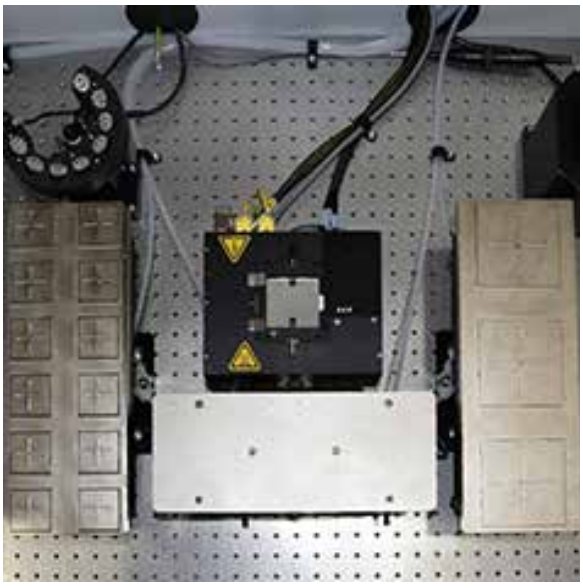
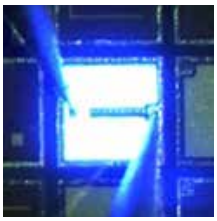
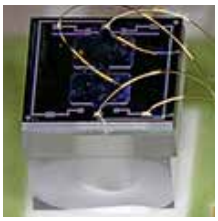


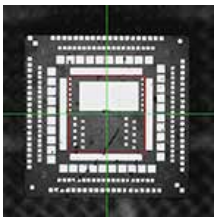
Figure 12 Palomar 50x58mm PHS Stage

PALOMAR 6500
DIE BONDER

The 6500 Die Bonder offers a balanced combination of accuracy, speed, and flexibility in a compact system footprint. The 6500 Die Bonder performs ultra-high accuracy eutectic and adhesive placements with cycle times under seven seconds using its four-axis positioning system driven by linear motors gliding over air bearings on a steel based frame.







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  VisionPilot with Radar Referencing pattern recognition software to maximize throughput.

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  Engineered for Industry 4.0 communications.

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  Cycle Time: to 1200 UPH, axis speeds near 40 ips with resolution of 0.1µm over work area.. Tool Change Speed: 0.25 seconds

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- **Placement Accuracy**
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- **DAC - Dynamic Axis Correction**
  Maintains positional accuracy through active thermal compensation

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  Achieve maximum ROI by adding a service contract complete with preventative maintenance visits.

TYPICAL APPLICATIONS

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- Solar concentrator packaging
- Silicon bench (V-Groove) placement
- Ultra-fine pitch hybrid assemblies
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- High-bright/high-power LED arrays
- LED printhead attachment

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Making the connected world possible by delivering a Total Process Solution™ for advanced photonic and microelectronic device assembly processes utilized in today's smart, connected devices. With a focus on flexibility, speed, and accuracy, Palomar's Total Process Solution includes die bonders, wire and wedge bonders, vacuum reflow systems, along with Innovation Centers for outsourced manufacturing and assembly, and Customer Support services, that together deliver improved production quality and yield, reduced assembly times, and rapid ROI.

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