Today`s telecommunications/datacom industry is coping with its own technical challenges in processing capabilities as it juggles demands for greater electrical performance and reduced sizes. Particularly hot in technical slate are automatic eutectic attachment techniques, which are desirable for high-performance and high-capacity die attach applications. Actually, the eutectic die attach technique is nothing new. This die bonding technique has been widely explored and employed, particularly on manual die-bonding equipment.

What is new, however, is its elevated place in an industry environment where current and future needs – high-volume and high-placement accuracy (up to ±5 microns) - so clearly call for flexible automated equipment. In particular, demands for high volume and high placement accuracy require automation that`s swift, precise and repeatable.

Understanding the Eutectic Concept
When different metals are combined into alloys, a range of melting temperatures is created with varying proportions of each metal used, such as Au/Si @ 363°C Au/Sn @ 280°C. Material phases - liquid, solid, plastic - and raster structure are usually depicted in "phase diagrams." These diagrams show a distinct mass ratio at which the solid state evolves into liquid state without passing the plastic state. This ratio determines the lowest possible melting temperature for the alloy, which is of great importance to the eutectic soldering process. During eutectic die attach, the substrate is heated to a temperature just below the solder`s eutectic temperature. During the bond cycle, an 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.

In many cases during soldering, a cover gas is employed, which usually contains a passive component (such as 90 percent nitrogen) to prevent metal oxides from forming, and an active component (such as 10 percent hydrogen) to break away existing metal oxides. The solder, usually precipitated to the die foundation (backside metallization) or to the substrate surface, can also be supplied as a 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.

Pay-off of Automation
The goal of automation is cost-effectiveness. The primary benefits are increased volume, consistent quality, cost avoidance and reduction. In some cases, benefits include the accomplishment of tasks that were otherwise virtually impossible to perform manually to specifications. These benefits are realized through improvements in assembly reliability, labor savings, assembly yield improvements, cleanroom floor space savings and the optimization of work-in-process inventory. State-of-the-art assembly automation, wherever effectively applied, has resulted in tremendous cost savings and renewed competitiveness.
Manual Processing Contrast
Although placement accuracy requirements usually are situated around ±2 mils, new demands calling for minimal and repeatable transmission lengths, such as microwave and optical component applications, narrow this requirement down to ±5 microns. Some companies have even reported manual mounting of active components down to ±1 micron placement accuracy.

The manual process has a very low capacity and requires a highly skilled operator. Additionally, 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. Present-day automatic die-bonding equipment permit multichip eutectic die attach packages to be processed and assembled in a single pass with mechanized substrate and die handling. Some equipment suppliers can provide a ±5 micron eutectic die placement accuracy as required for high-frequency devices.

Flexibility Requirements
Automatic workcells must provide the flexibility to support different carriers, such as wafers, waffle packs and Gel-Paks, and a range of attachment methods, such as eutectic die attach, epoxy dispensing or stamping. The workcell must allow full automation by incorporating SMEMA-compatible conveyors to present materials and transport completed parts. Changeovers and implementation of new processes are critical, and these should be encompassed by flexibility.

Designing for Automated Equipment
While design engineers typically develop products on manual die-bonding equipment, today’s business focus must be on gaining competitive advantage and anticipating future demands and technology shifts that will force manufacturers into an automated process. Naturally, automatic workcells perform best when parts are presented in an orderly fashion, with consistent dimensions and appearance. It requires a certain effort to fit a manual bonding process to an automated process, and design engineers should be concerned about automated process requirements early on in the development phase to ensure workcell effectiveness.

Critical Control Parameters
Manufacturers usually specify process conditions, often gained from in-house experience, such as how much solder reflow is desirable to achieve sufficient mechanical bond strength and to prevent voids between die and substrate.

Although every application has its own specific set of requirements, with some machine parameters more critical than others, all need to be in proper proportion to obtain desired results. Critical control parameters include head force, background temperature and incremented thermal energy, soldering time 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. Too much force can damage a component - by introducing micro-cracks that may affect electrical performance, for example. Small stress-sensitive die ranging up to 20 mils can take a fair amount of head force, typically up to 50 grams. Larger die generally require head forces of 100 grams or more.

Background temperature and incremental thermal energy: The substrate is heated to a background temperature, which is boosted during bonding until reflowing occurs. The background temperature determines the amount of incremental thermal energy needed to initiate solder reflow. It indirectly controls soldering time. An example of a heater stage is show in Figure 2.
Soldering time: The time span of head force and incremental thermal energy largely determines the extent of solder reflow and also impacts throughput time. Actual soldering time varies from a few seconds to a dozen seconds, depending on die size.

Cover gas: The flow of cover gas affects the rate at which the solder refloows and determines the quality of the inter-metallic bond.

**Eutectic Advantages**

Eutectic die attach offers a number of advantages over similar techniques, of which good thermal solder conductivity and immediate fixing after bonding are most significant. As eutectic solder provides good thermal conductivity characteristics with respect to epoxy, this method is suitable when a high degree of thermal dissipation is required, as in radio frequency amplifier applications. Although eutectic soldering processes are slightly harder to qualify process control than similar techniques, such as conventional silver-filled epoxy dispensing or stamping, they do have a clear advantage in the attachment of power devices because of enhanced thermal dissipation.

Die are fixed immediately after the collet separates from the die. No curing operation is necessary. With epoxy dispensing or stamping, accurate die placement is not guaranteed until the parts are safely transferred to an oven and cured. Eutectic die attachment takes a bit longer, but it is safe from die migration and does not involve any curing operation.

**Meeting Accuracy and Throughput Demands**

Several eutectic die attach methods can be used to successfully meet accuracy and throughput demands.

**Scrubbing:** Adding thermal energy can easily be controlled if the bonder allows scrubbing, which is translating load force into frictional heat by cyclically moving the die back and forth and/or left to right while exerting head force. If the number of scrubbing cycles and the displacement are programmable, this option offers great flexibility. Scrubbing requires eutectic die collets, which are typically composed of tungsten carbide, with either two or four slanted sides to support the die by the edges (Figure 1).

Each eutectic die collet is tailor-made and fits the parts tightly to minimize drift during scrub. Nevertheless, a small amount of drift is usually noticeable in the scrub direction only. Therefore, the scrub direction is chosen perpendicular to the direction with high accuracy demands, which yields good results. Figure 3 represents eutectic die placement on a heated substrate, indicating substrate, die, preform and die collet location. Note the potential scrubbing directions.

If the workcell offers flexibility to interact with third-party devices, a temperature controller with a low mass heat conductive strip can be used to provide the additional heat needed for solder reflow. This allows for fast heating and cooling. These devices usually control heat by mastering current flow through the strip, which acts as an electrical resistance. The workcell triggers the heat controller, as the bond head exerts force on the die, for example. The background temperature is set below reflow temperature, and temporarily ramped up and held at a certain level, such as 10°C or higher above reflow temperature, depending on desired process cycle time. This method has been shown to work well with solder preforms. While scrubbing is not required, it may be beneficial for increased throughput.

**Machine Restrictions**

With the more pronounced demands for accuracy, close attention must be paid to mechanical imperfections, inherently connected to axis motion. Key areas for attention: picking die close to the place site, presenting die in an orderly fashion to minimize rotational head movement and carefully tuned machine parameters.
As for the vision system, die presentation in wafer form or die orderly arranged in a waffle pack can significantly reduce the time needed for an automatic vision system to accurately locate a component. Also, repeatable sawing may reduce pick-and-place offset, as the vision system recognizes patterns on the component rather than bare edges. This is important when components need to be carefully aligned to ensure proper functionality, such as laser diode die on a carrier. Gold precipitation on top of the laser diode, which serves the wire-bonding process, is not always accurate enough to locate a diode’s optical center. Specific marks or alignment points often are available for manual referencing, but are not always as easy to recognize by a vision system.

At higher placement accuracy, effective inspection methods become more difficult to find with standard optical equipment. High focal depth and magnifications up to 500 times are minimal requirements for valid inspections, let alone measurements. The vision system proves to be valuable for automatically inspecting proper placement on completed parts and storing placement accuracy data. But placement accuracy entails more than positional and angular offset - it also concerns horizontal flatness of the die on the substrate. Even slightly tilted die can cause positional offset when placed into the package.

**Application Examples**

Eutectic attachment applied in a telecommunications application uses stacked laser diode die and heat sinks (approx. 15 mils square by 10 mils thick) on a carrier. Placement accuracy is typically very narrow (±12 microns), as little variation of the optical path is allowed to avoid optical distortion. Solder reflow can be induced after each die placement or for all components at once. In this case, solder preforms are used, which adds up to a total of four distinct parts per stack. Clearly, precise machine control is necessary to avoid component drift during reflow. The part was bonded on a heat strip for fast heating and cooling, as previously mentioned. No eutectic die collets were necessary, because no scrubbing was employed. Figure 4 shows eutectic attachment of exceptionally slim die (20 × 200 mils) for a microwave application.

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 difficult to maintain. In this case, to avoid offset during placement, perfect horizontal flatness of the eutectic die collet is essential. Scrub is used to provide the additional reflow heat. Solder is precipitated at the foundation of the die. The part is bonded on a fixed temperature-controlled heat stage. Specially designed eutectic die collets are necessary to ensure proper scrubbing.

**Summary**

To meet the telecommunications and datacom industries’ demands for volume and placement accuracies, flexible automatic workcells are required that support different carriers, methods and automatic materials presentations. The eutectic process, while time-sensitive, is capable of handling the technical requirements involved in recent packaging developments. Meanwhile, packaging demands continue to evolve, requiring higher and higher eutectic placement accuracies. Automated workcell capabilities pose significant technical challenges. Select equipment manufacturers presently provide off-the-shelf workcells that answer these demands.
Figure 1: Eutectic die placement collet.

Figure 2: A typical hot stage as used in eutectic attachment applications.

Figure 3: Eutectic die placement on a heated substrate.

Figure 4: Eutectic attachment of exceptionally slim die on a microwave application.