Advanced Hybrid Die Attach Equipment

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Hybrid die attach represents a convergence of advanced SMT and IC technologies. Equipment serving this market must be extremely flexible to bond many different components while applying two or more different epoxies, in a single pass. It must process the smallest to the largest, and also ultra-thin, die. Various single-pass component presentation methods are required and the equipment must work with many different substrate types. Key bond process parameters such as placement accuracy, bond-line thickness, die tilt, epoxy coverage and fillet, must be met.

A die-attach machine consists of the five major subsystems: pick-and-place, component presentation, substrate presentation, vision, and epoxy dispensing. All of them need to be evaluated under the specific terms of a given application (Figures 1, 2, 3).

**Pick-and-place system**

Compared to ball-screw or belt systems, linear-servo pick-and-place systems with positional feedback offer superior accuracy. To achieve this, encoder resolution must be about ten times the required die placement accuracy. If die placement accuracy is less than ±10µm@3 sigma, it is crucial how the system compensates for temperature change. At a minimum, a glass-board test is required to demonstrate bonding accuracy under controlled conditions.

Next consideration: mechanical stability at the point where the pick-up tool, requiring frequent changing during hybrid applications, and the bond-head engage by locking together (Figure 1). Additional evidence of mechanical stability can be found in the processes used to calibrate planarity and verify placement accuracy. Calibration should be required infrequently and guided by the operating software with simple step-by-step instructions. Accuracy should be verified by a glass board test that is well-documented with all calculations explained in detail.

The system must include bond-force calibration to maintain bond line thickness and prevent die damage due to excessive force. Automatic calibration via load cell provides a consistent bond process. A load cell is also used to automatically calibrate the needle for epoxy writing, which is critical for maintaining the required gap between the tip of the needle and the substrate. The operating range should cover 0 to 1000 grams of bond force. Lower force is important for bonding very thin die, or die with sensitive features such as air bridges and vias found on gallium arsenide (GaAs). High bond force (1000 grams or more) is critical for very large die or applications requiring high viscosity epoxy.

**Component presentation system**

A die attach machine should support all standard formats of component presentation on one machine in a single pass, including all sizes of wafers, waffle packs, Gel-Paks and grip rings. Waffle vision (automatic component search), which provides searching for die in large waffle pack cavities, is also a critical feature. Depending on the application, total component capacity and/or total number of different components is a very important consideration.

Automatic wafer presentation systems (Figure 2) should efficiently present large quantities and multiple types of components to the pick and place system, up to 200 of 50mm waffle packs or Gel-Paks, up to 25 different wafers or grip...
Assemblies, or a combination of these, in a single pass. Easy loading and unloading is advantageous, as is detection of ink dots, missing corners and partial die rejects. Wafer mapping, which directs the pick and place system, will precisely locate good die on non-inked wafers. To maximize yield, and minimize cost, especially in higher-volume applications, the die should be picked directly from the wafer.

A hybrid die attach machine should accept tape and reel feeders for presenting SMD components. It should accommodate feeders for 8 to 44mm tape, 10 to 20 of those for 8mm. High-accuracy component centering is required, especially for 0201-component processing.

Most important here is flexibility. For hybrid applications, the handling of as many as possible, different components is the best solution. The die attach platform should be flexible enough to accept custom presentation systems and be ready for new requirements as markets change.

Substrate Presentation System

There are several types of substrate presentation systems, including belt, gripper, walking beam and manual work holder. Belt-transport systems (Figure 3) and manual work holders are most widely used for hybrid applications because of their overall flexibility.

Flexible tooling that is easy to use and can be changed over quickly is important, as is a touch probe that provides quantitative feedback so that adjustments can be made for planarity. Recommended is a touch probe with 1µm repeatability. Gripper and walking-beam indexers are less flexible, and are used for the more dedicated IC die attach.

In addition to flexible tooling, a substrate presentation system should accommodate a wide range of substrate sizes, from under 50mm to 200mm, on a standard edge belt, on Auer Boats or on custom carriers. Generally, presenting different sizes and types of substrates includes substrates under 50mm and flex over 50mm to 200mm as well as TO-Packages. Substrate presentation includes Auer Boats and custom carriers, standard edge belt and edge belt with custom carrier.

A substrate presentation system has to be SMEMA-compatible so that it can operate in-line with equipment including curing oven and conveyors. Options should include conveyor buffers for manual loading and unloading, single- or multiple-magazine input and/or output, in addition to leadframe/bare-board unloader.

Vision System

With vision systems, it is crucial to look for a dedicated, experienced vision engineering group with a commitment to continuous improvement of vision hardware, software, illumination and optics. A vision system is composed of four major elements: vision engine, wafer/component camera, substrate camera and upward-looking camera.

Minimal vision hardware should have an advanced 256-gray-level vision engine that utilizes a commercially available vision card. A component camera is required to provide inspection and align the die for ensuring proper orientation prior to picking. This camera is mounted either on the bond head or in a dedicated, fixed position. For maximum flexibility, some die attach machines provide both mounts.

A substrate camera is required for alignment to substrate fiducials and inspection of reject marks. For added functionality, the camera should align components prior to picking, perform pre- and post-bond inspection, with automatic offset adjust, and read 2-D code on the substrate.

An upward-looking camera, mounted in a fixed position inside the machine, is required to align the die after pick-up. Care must be taken as poor dicing can affect placement accuracy when aligning to the bottom edge of the die. As a remedy, there is an intermediate placement tool (IPT), which uses the substrate camera and a temporary placement station to accurately align and place components relative to the patterned portion on top of the die. Relying on the bottom edge of the die will often cause an alignment offset (Figure 4).

Camera systems should have motorized auto-focusing and support all available algorithms and, most importantly, programmable vertical and oblique light level control.

Figure 3 - Belt-transport presentation system

Figure 4 - Poorly diced 0.25mm die with irregular edges
The three cameras should work independently to enable individual optical and lighting settings. Light levels for each program must be savable since they can be different for each algorithm used.

**Vision system algorithms**

A die attach machine should be supported by a comprehensive library of vision algorithms, and an engineering group willing to develop new algorithms for unique requirements, including pattern/template matching, circle matching, edge search, center-point search (blob analysis), symmetrical, and multi-search.

Pattern or template matching (Figure 5) enables the programming of unique features or dedicated fiducials. This does not require templates of any specific shape or construction to recognize features as small as 150µm, depending on camera magnification and the selected algorithm.

Circle matching (Figure 6) is used to locate the center of a circular pattern, for example, the center of a TO-header.

The edge-search algorithm (Figure 7) allows the programming of component edges. This is useful when there is no unique pattern, or when component placement is edge-dependent.

Centre-point search, or blob analysis, is a binary algorithm permitting a feature of a certain size be taught to the system as a ratio of dark and light pixels. The algorithm can be programmed to find the centre of a group of dark or light pixels. Software filters can be set to have the vision system reject features too large or too small. This is very useful in hybrid applications where ceramic thick-film substrates don’t always provide clear, consistent fiducials.

Multi-search capability allows linking multiple vision algorithms within the same field of vision (FOV). Thus, the first search could be a ‘coarse find’ of a unique feature. Subsequent searches would utilize pixel vectors from the first search to target specific features that may not be as unique. The multi-search function can use one vision algorithm for a group of searches, or be programmed to use various algorithms.

**Additional vision features**

Additional vision features for hybrid applications include three-point substrate search, substrate check result measurement, relative placement, waffle vision, and pre- and post-bond inspection. Three-point substrate search (best fit) corrects scaling for inconsistent materials such as ceramics subject to varying degrees of shrinkage after firing.

Substrate-check result measurement is used to set pass/fail criteria for inconsistent substrates. It measures the distance between two fiducials or search features, and compares the distance to the originally taught substrate. A failure threshold is settable down to 1µm. Substrates that do not meet this user-defined threshold are rejected.

Relative placement permits the programming of a local eye-point and of a defined position vector for placing a component in relation to a reference point. Relative placement is typically used with hybrid devices where a compo-
component must be placed in exact reference to a feature of another component already placed. Examples are die stacking and opto-applications, such as placement of emitter and receiver on the same substrate, or component arrays that must be precisely spaced.

Waffle vision, or component search, reliably locates components in waffle packs, where die size is significantly smaller than cavity size, regardless of die orientation. Waffle vision can make use a search pattern to find fiducials outside of the vision camera’s field of vision, in addition to finding patterns or templates of any orientation. This eliminates manual re-orienting of the die. Machine operation is more efficient if the die are oriented correctly in the optimal cavity size. Ideally, cavity size should be no more than 1.3 times die size.

Pre- and post-bond inspection is an important tool for observing component placement during production, at user-defined search intervals. This includes automatic on-the-fly placement correction, programmable warning and error limits, small-dot adhesive inspection and real-time statistical data such as mean placement, standard deviation and Cpk.

Dispensing systems

Ideally, a system would support many different dispensing techniques, including epoxy writing, stamping (dip and dab) and cross-needle dispensing, and it would dispense two or more different epoxies from independent dispensers in a single pass.

Preferred dispensing techniques include volumetric (auger screw) dispensing, time/pressure dispensing with multi-needle shower head, stamping/gang stamping and epoxy writing with programmable dispensing patterns. Process control and automatic programming should ensure a consistent epoxy pattern and volume, X-Y speed and auger speed. An epoxy low-level detector is also important for continuous operation.

High-performance volumetric screw-pump dispensers yield a highly repeatable epoxy dispensing from large patterns to ultra-small dots, with the same needle (Figure 8). This eliminates multiple custom stamping tools, which can be costly and difficult to maintain. Additional features include solder-paste capability, easy removal and cleaning and automatic needle calibration.

Epoxy stamping is necessary because some epoxies cannot be dispens. A rotary squeegee unit with a stamping tool can adjust the epoxy amount, doing fine adjustment via micrometer.

Adhesive stamping is an excellent option for printing small dots or patterns using standard stamping tools, custom designs or gang-stamping tools. The method utilizes a rotating stamping dish. Film thickness is controlled via micrometer-adjusted doctor blade. Adhesive stamping achieves repeatable results on warped substrates, and substrates with thickness variations. The dish and blade should be easily removable for cleaning.

Any vendor specializing in custom projects should provide a flexible, modular die bonder that accommodates flip-chip die sizes up to 50mm, includes a well-designed cavity fluxing system, and offers 10µm placement accuracy. Flexibility is a must for all five of the die bonder subsystems: pick and place, component presentation, substrate presentation, vision and dispensing. Last but not least: the installed base of some of the equipment selected should include major IDMs and subcontractors. In conclusion, only the most flexible hybrid assembly solutions will safeguard hybrid production well into the future.

The bottom line: flexibility

In the fast-paced hybrid market, customized jobs are the order of the day. An equipment vendor should be in a position to accommodate these custom projects. For low volume/high mix production, a basic manual-load die attach system will be sufficient. For high-volume, or high-mix, production the die attach system must be operable in-line with ovens, wire bonders, screen printers, laser markers, plasma cleaners, etc.

If the procurement budget permits just basic die attach, it is good policy to include all the technical features for easy retrofitting later when requirements change and business grows. To accommodate ultra-thin die down to 50µm, features such as needle-less ejection, synchronous ejection and an ultra-light tool are needed. To accommodate new materials, there may be a need for heated pick-up tools and substrates, heated press, tool changers, carriers, component presentation systems, illumination, dispensers, etc. Important are examples, references and an organization chart that illustrates how a custom project will be handled.

Figure 8 - Epoxy dispensing - large patterns to ultra-small dots