Advanced Packaging

Automating Hybrid Circuit Assembly

Die Attach

The demand for hybrid circuits has remained strong as emerging and existing applications continue to rely on this proven technology. Developers of applications such as medical, military, photonics, wireless electronics, and newly miniaturized devices find the need to integrate multiple devices and technologies to achieve performance goals. Hybrids are flexible by nature and advantages include a small footprint and a rapid development cycle. While advances have been made in the hybrid products, advances also have been made in the automated processes to produce these products. These advances include throughput and yield improvements. Epoxy dispense systems have become more sophisticated and capable of much greater control. Pick-and-place systems have improved in die handling, as well as in software capability. This article presents an overview of multiple aspects of automated hybrid assembly such as material presentation, vision, and attachment technologies, with an emphasis on what is new for each aspect.

Hybrid Component Handling

Assembling hybrid electronics means handling a large range of component types and sizes. These can vary from small die only 0.008 $in.^2$ to large alumina substrates several inches long. Of critical importance are bare die placements, which require delicate handling. Force must be carefully controlled both during the pick and during the place cycles. Force control is necessary to avoid damaging die and to achieve good epoxy coverage. Force should be programmable for each component used in the hybrid. Small or delicate die may only tolerate forces as low as 10 g, while larger parts or die attached by thermocompression may require several kilograms of force for bonding.

Surface pickup tips are used to handle most hybrid components. A surface pickup tip is a round collet or nozzle that is placed on a portion of a component’s top surface to provide a vacuum seal. Perimeter and pyramid collets are for special applications. A perimeter collet has walls that contact only the outside perimeter of the die. They are commonly used for gallium arsenide (GaAs) or indium phosphide (InP) die, since these materials are fragile and require special handling. Pyramid collets are for eutectic die bonding applications and have a wall at a 45° angle that overhangs the side of the die. By contacting the side edges instead of the top surface, it is possible to scrub the die (small *x* and *y* movements) without contacting the top active surface of the die.

Figure 1. *Automatic tool changing provides capability for handling the widest range of components and die.*

Automatic tool change banks provide a large assortment of tips and collets (Figure 1). Tip turrets change tools very quickly and can offer an advantage for eutectic applications, such as RF power amplifiers, that call for a different tool for the solder preform and the die.

High Precision

Die need to be placed with a high degree of precision. Frequently for performance purposes, the die must be placed with a particular accuracy relative to other devices, fiducials, or features. An example is placing microwave devices along a transmission line. Proper positioning is also necessary for the optimal attach in the epoxy or solder. Downstream equipment such as wire bonders and test systems require a high level of accuracy and repeatability for optimal performance.

To achieve this level of accuracy, automated assembly equipment must begin with the appropriate platform, one that is composed of materials that are stable regardless of temperature or humidity fluctuations. This can be achieved with granite or advanced polymers. A recent development in machine design is to use mineral castings for the base material. These castings provide dramatic improvements in vibration damping and thus allow for higher production speeds while still maintaining high accuracy. For motion control, linear motors with optical encoders are used for rapid and accurate movements with high precision. Cantilevered robots can suffer serious losses in accuracy and speed and should be avoided. For practical use in automated assembly, the system design must be such that frequent calibration is unnecessary.

Vision and Lighting

Machine vision is a critical machine component to ensure accurate assembly of randomly presented parts. The machine vision system must be robust both in how it finds components and how it references the assembly circuit. Effective vision systems can quickly find and align parts no matter how they are presented in waffle packs over a full 360°. This is important to avoid the need for pre-alignment of die by operators and to ensure that all of the good die presented are actually used. For hybrids, assembly machines must be capable of multiple magnifications to process features on small die and large substrates. Software, hardware, lighting, and optics are integral to a vision system.

A recent advancement in vision systems is the use of programmable lighting. The availability of both collimated and ring lighting are the minimum requirement for finding a broad range of features. Programmable lighting goes beyond this by enabling the user to select from a wide spectrum of lighting intensities for all light sources. One set of light settings can be used to find a die in a waffle pack while a different set is used to locate specific features on the die. Ideally, lighting can be set independently for each die type or substrate/package alignment point.

Another vision enhancement achieved through software is split fiducials alignments. A requirement may exist to align a die to a feature in one axis, such as a die edge to a substrate edge, while also aligning to another feature in another axis, such as a die bond pad to a substrate bond pad. This is known as ‘split alignments,’ and is required for some microwave and photonic applications.

Material Presentation

Very high part counts and product mixes are typical challenges for automating hybrid assemblies. Thus it is necessary that automation equipment is robust in terms of handling the input of materials. Most commonly, materials are presented in waffle packs, gel-paks, tape and reel, or directly from wafers (Figure 2). Picking die as thin as 0.002 in. from a wafer presents a special set of challenges. Controlling the speed with which the eject needles push the die from the tape and synchronizing the eject needles with the movement of the pickup tip enable success. A clever approach to picking high aspect die from a wafer is to rotate the wafer before raising the eject needles. The vision system finds the die, and then a motor rotates the wafer to align to the eject needles.

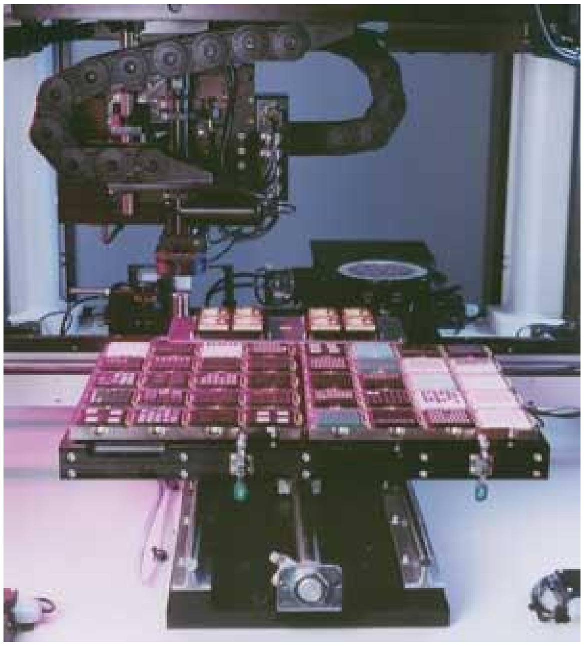

Figure 2. *Of all microelectronics, hybrids require the highest mix of material inputs such as waffle packs, gel-packs, and tape and reel.*

Ideally, a machine can be simultaneously loaded with enough variety of components for all of the hybrids that will be processed on the machine. Shuttling in and out of waffle packs should be avoided. If many different component types are used in the hybrid, too much time is spent shuttling through trays of components just to build one unit. Small die cannot be shuttled in without being disturbed in the waffle pack, and are better presented on a stationary stage.

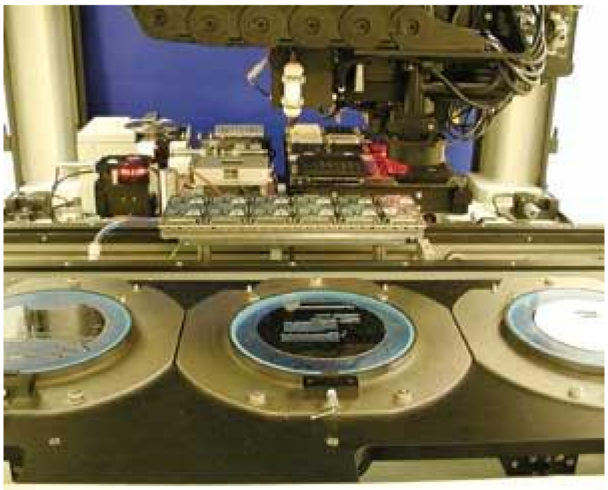

Figure 3. *Picking die from multiple wafers adds a key aspect of bare die capabability.*

Assembly equipment is used in line with other equipment. An epoxy dispense machine might be placed before the assembly station and an oven or wire bonder might be placed downstream. In these cases, substrates or packages usually are introduced to the machine on a boat or leadframe and carried by conveyor. Packages are lifted from the boat and held on an assembly stage by vacuum. Conveyorized systems often use bar coding to provide traceability to the assembly workcell. Current systems can read 2-D bar codes and record data that can be traced back to each package in a boat (Figure 3).

Software Interface

Assembly equipment software is an opportunity to turn a simple machine into a powerful tool. The minimum requirement is for software to allow die and placement locations to be taught for use in the future. Enhancements beyond this include the ability to use die in multiple programs and to re-teach easily. Alternate die capability allows the system to automatically switch between alternate vendors of die. Sophisticated database structures permit control of many production parameters by even casual users. Graphics are a helpful addition to the interface. Pickup tips can be ‘virtually’ overlaid on a die while it is taught to ensure tip size and pickup point are correct. A die outline can be overlaid on the substrate to guarantee placement location. For epoxy dispense machines, camera mode simulation can draw the locations of the dispense tip while the machine traces out programmed patterns.

XML is a format of choice for databases that will be accessed by multiple applications. Using an XML database allows for easy generation of programs from CAD software or standard office applications. Outputting traceability data in an XML format makes for easy manipulation of the data so that it is valuable for downstream machines or quality control analysis.

Die Attach Techniques

Typically hybrids are built using epoxy die attach techniques for most components. This is increasingly combined with some eutectic attach and some flip chip bonding. Epoxy control has always been a critical element of the assembly process. Epoxy must be controlled to provide good substrate and die coverage. Epoxy volume must be limited to avoid bridging and excessive squeeze out which risks shorting to other components. Controlling gap, the distance from the dispense needle tip to the substrate surface, is one key to good dispense performance. Good gap control is achieved by mapping the dispense surface as a plane using three point laser height sensing. Hybrids often are relatively large, and height differences are accentuated across the board. A consistent gap can be maintained if the plane is mapped and the dispenser conforms to the topography as it is determined.

Epoxy stamping is used when the process calls for very small dots. Stamping, also known as pin transfer or daubing, involves using a compliant tip to touch down in an epoxy well to acquire the epoxy and then to transfer the material by touching down on the substrate. A micrometer adjustable wiper blade is used to control the epoxy thickness in the well. Dot diameters as small as 0.004 in. can be achieved by stamping conductive epoxy. Dots this small are necessary for small FETs, beam lead diodes, and some photonic devices.

Eutectic die attach is used for devices that require a very reliable means of attach such as high-power amplifiers. Gold-tin, gold-germanium, and gold-silicon are three common eutectic alloys. To automate this process, the package or substrate must be presented on or moved to a surface that can be thermally controlled. The pick-and-place system moves the solder preform and die to the substrate and ramps the temperature to achieve reflow. Ideally, temperature ramp is performed quickly for throughput and quality issues. The process must occur in an inert environment to avoid oxidation. Good coverage is obtained when the system can be programmed to scrub the die into the molten solder.

Flip chip technology is an important addition to traditional hybrids. A hybrid with flip chip die has the advantages of flip chip, such as improved electrical performance, better board space use, and the possibility of higher I/O count - while being a relatively simple device to assemble. The integration of an uplooking camera and vision software to process bumps makes flip chips achievable on higher-end die bonders. Technology for assembling with flip chips has developed significantly as equipment suppliers have introduced dedicated flip chip bonders.

Conclusion

Advances in assembly equipment for building hybrids have kept up with the challenges posed by new applications for hybrids. Design and construction of hybrid assembly equipment enables dramatically higher pick-and-place accuracies, yields, and speeds. Machine vision is faster and more powerful for processing challenging components. Equipment advances combined with local service and applications support ensure success. The result is that hybrid circuit technology and assembly techniques continue to evolve to meet new challenges.

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