Advanced Packaging

Automating Military Hybrids and Microwave Module Assembly

Automated assembly produces consistent, higher quality hybrids and modules at a lower cost.

BY DAN CROWLEY AND PETER CRONIN

Military hybrids and microwave devices are a distinct subset of microelectronics assembly. Because these devices emphasize power, reliability and robustness in harsh operating environments, assembly techniques require a high level of precision, particularly in the areas of dispensing epoxy and handling die. Bond line thickness, for example, must be exact, and this thickness is determined by carefully controlling the volume of epoxy dispensed. Die and other components require precise and repeatable placement for electrical functionality and to avoid post-test tuning (Figure 1).

The assembly of military hybrids and microwave devices has become difficult due to increasingly stringent design and performance requirements. Precision, control and repeatability are essential for achieving acceptable yields, and this can only be accomplished through automated assembly. Yet, automating assembly presents special challenges to automated equipment providers. Advanced vision systems, stable gantries, high-accuracy motors and sophisticated software all contribute to a system's ability to meet these challenges. Yield improvements result from better use of available components (fewer raw material rejects by the vision system), more parts passing post-assembly inspection and improved results through test.

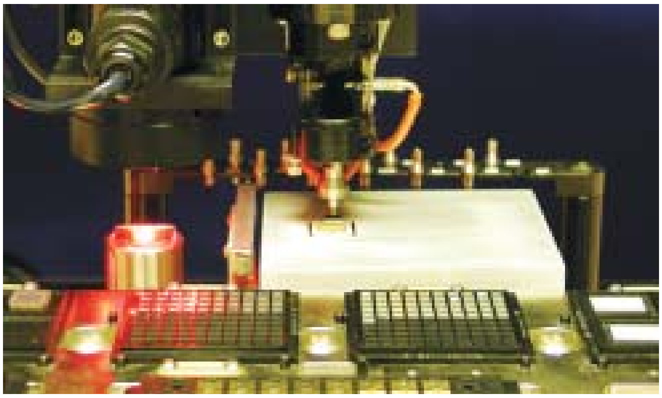

Figure 1. Die and other components require precise and repeatable placement to avoid the need for post-test tuning.

Automated System Requirements

Effective automated assembly systems comprise many elements. To achieve high yields, one must first consider platform characteristics, material presentation, material handling, machine vision and system software. Vital platform characteristics include gantry size and construction materials. The system's materials determine its ability to maintain accuracy despite temperature changes. Choice of materials also directly affects system accuracy while operating at high speeds.

Materials presentation is key to achieving high yields because component handling must be limited. For example, automated systems should accept all material input types, such as waffle or gel-paks, wafer and tape-and-reel, to avoid the manual transfer of parts (Figure 2). Material handling involves processing boats, custom carriers and lead frames. Using these tools allows for standardization across a line and avoids manual handling of work in process. Sophisticated machine vision allows for variation in material appearances over time and for robust acceptance of component inputs. The ability to accept all die regardless of orientation over 360° allows for the use of die directly from the supplier without manual pre-orientation. System software contributes to higher yields by tying together all system elements and adding features, such as die placements relative to previously placed die, CAD download and traceability. These elements apply to all systems that make up an automated microelectronics assembly line from epoxy dispense and die bonding to wire bonding.

Automated Epoxy Dispense

Epoxy control is an important concern of process engineers involved in building military hybrids. Bond lines must be of specific dimension and volume to ensure good thermal properties. Squeeze-out must be controlled to prevent shorting or bridging. Placement accuracy must be maintained strictly so that high-frequency components operate properly. Full epoxy coverage with no voiding is critical to maximize thermal transfer and minimize stress. Military hybrids cannot tolerate voiding for electrical reasons.

They also require complete coverage for proper heat dissipation. Heat not dissipated in local areas can change device char-

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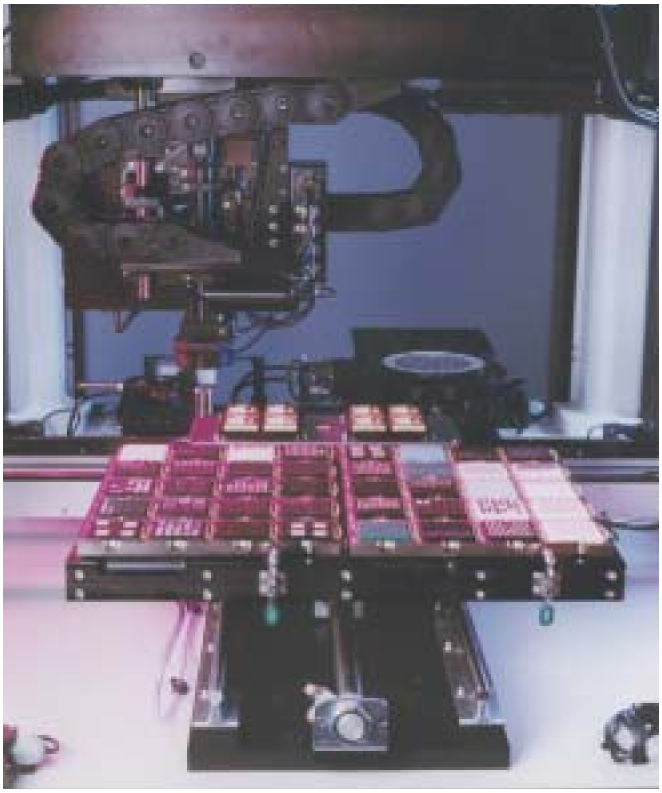

Figure 2. Materials can be presented to a system in waffle packs, gel-paks, wafer, tape-and-reel or in boats.

Figure 3. Some of the smallest components, such as 0201 capacitors, require epoxy dots as small as 0.004" to be stamped.

Figure 4. Conveyorized eutectic bonding for high power devices.

acteristics as a function of temperature and can lead to catastrophic failure. Bond lines must be controlled for thermal and mechanical reasons. Microcracks can be induced if the bond line is not optimized to account for mismatched thermal coefficients of expansion (TCE) between the die and substrate or between the substrate and package. Automated equipment must be capable of all this and be fast and reliable as well.

There are several challenges in dispensing epoxy. These include creating small dots, dispensing areas for 100 percent coverage while controlling the bond line and using multiple types of epoxies. While a positive displacement pump generally dispenses lines and areas, pumps cannot consistently dispense dots smaller than 0.008" in diameter. When a smaller dot is needed, epoxy stamping should be used (Figure 3). This technique is used frequently to achieve small epoxy dots. Sometimes known as daubing or pin transfer, this technique relies on a compliant tool touching down in epoxy and transferring the material to another surface. The key parameters to control in stamping are epoxy thickness and tool profile.

Frequently, there is a need for multiple epoxy types in a single application. Conductive and nonconductive epoxies can be used in single applications and sometimes on single components. For example, end-terminated capacitors and resistors are attached with conductive epoxy, but staked with nonconductive epoxy between terminations. Nonconductive epoxy mechanically stakes the center of end-terminated components, while simultaneously blocking the migration of silver particles from the epoxy under the terminations. Sometimes, different conductive epoxies are needed in one application due to different component requirements. In these cases, the dispense system must have multiple pump capability, and, ideally, easy changeover between multiple pumps or a pump and stamping head pair. Flexibility is achieved when the pumps and stamping tools are attached with a common mount and can be changed over quickly.

Automated Die Bonding

Die bonding as it applies to military hybrids and microwave devices involves epoxy bonding, eutectic bonding and flip chip bonding. The highest yields with epoxy bonding are achieved with systems using the machine characteristics described above combined with epoxy control. Die placement into epoxy must be controlled carefully with closed-loop force control and ultra-high-accuracy placements.

Increasingly, eutectic materials are being used for die-attach with high placement accuracies. Eutectic solders such as gold/tin, gold/germanium and gold/silicon allow for excellent thermal transfer and are used for high-power microwave devices such as radar transmitters. To perform automated eutectic die bonding, it is necessary to handle small, delicate solder preforms, control temperature ramps and scrub the die in the molten solder — all in an inert environment. This is possible with in-situ eutectic bonding or in-line bonding. Reflow vacuum chambers may be used when accuracy is not critical. The highest yields with eutectic bonding are achieved with well-developed processes on systems that offer flexible process control (Figure 4). The epoxy-attach method requires the application of consistent, even layers of conductive material, as well as extremely small dots. One singularly important parameter is proper epoxy coverage under the die and filleting at the outside edges of the die. The thickness of dispensed epoxy, material characteristics (e.g., viscosity and particle size) and placement force will dictate the final bond line, coverage and filleting. The use of components as small as 200 µm and as thin as 50 µm make precision dispensing critical.

Flip chip bonding continues to increase as manufacturers take advantage of the smaller footprint and improved heat transfer characteristics offered by flip chip. The elimination of the need for wire bonding by using flip chips offers the possibility for increased reliability for military hybrids and microwave devices. However, flip chip technology requires automated dispense technology to achieve void-free underfill to encapsulate the area between the active side of a flip chip and the substrate upon which it is mounted. The underfill material protects the interconnect area from moisture and other environmental elements and reinforces the mechanical connection between the substrate and the die. Void-free, successful flip chip underfill is a reliable process that depends on the technology used, appropriate process parameters, attention to accuracy, equipment design, and appropriate dispense materials and patterns. Proper application process development is key. Once the process is optimized, throughput can be enhanced (with corresponding high yields) through dual-lane processing and the use of appropriate pump technology to maximize yields at the lowest cost of ownership.

Conclusion

Automated assembly produces more consistent, higher quality hybrids and modules at a lower cost. Precise epoxy dispensing and die placement results in consistent gaps between adjacent components. Tighter placements minimize wire lengths and, thus, minimize the amount of required tuning. This results in higher yields at both the assembly and test levels. **AP**

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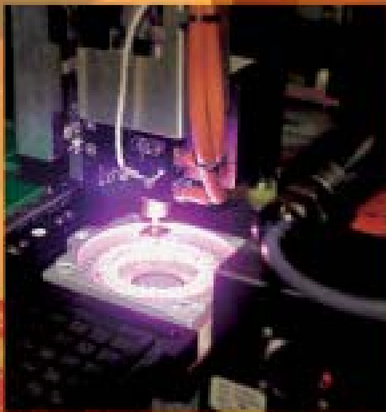

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