Pulsed-laser Heating for Flip Chip Assembly

A stress-free alternative

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As flip chip applications increase, corresponding demands for faster, reliable manufacturing methods follow. Using lasers for soldering and micro-welding provides advantages over traditional oven reflow or thermode soldering/bonding methods. The localized heat and short pulse generated by the laser assures that minimal thermal stress is applied on the area beyond the joined surfaces.

The short laser pulse results in lower thermal stress on the chip and substrate, as well as the interconnections that join them. This is because the exact amount of thermal energy required can be provided in one short-duration laser pulse. Because laser heat is localized, temperature can be applied selectively in the interconnection areas of interest. As a result, it is unnecessary to heat an entire substrate up to reflow temperatures to melt and reflow an interconnection of a few microns. Laser technology enables pick-and-place and assembly reflow heating to be accomplished in one step, at the same location, providing added time savings for faster throughput.

ACF and NCP Material

Thermal stress introduced during flip chip assembly is a significant concern in the reflow process. The heat required to melt tin or lead alloy solder interconnections generates high thermal stresses on both the chip and substrate. This creates manufacturability problems and reliability concerns. Additional negative factors include the high cost of the materials and productivity losses due to the nature of the process.

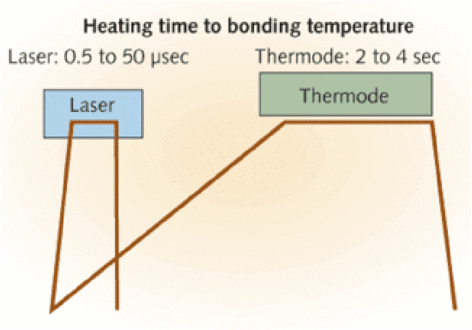

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Figure 1. *Thermode bonding vs. laser bonding.*

Some materials used in the flip chip assembly process, such as anisotropic conductive film (ACF) and nonconductive paste (NCP), are expensive, and contribute to a high overall process cost. In such circumstances, using a laser-assisted system can reduce the time required to make the bonds, and also reduce or mitigate the overall temperature and thermal stress placed on the chip and substrate. Table 1 shows a comparison of the soldering times required for reflow, thermode, and laser soldering. Figure 1 depicts the relative pulse time and thermal mode of a laser-assisted system and a standard thermode system.

Adhesive Joining	Temperature (°C)	Time (sec)
ACA (anisotropic conductive adhesive)	150 – 180	5 – 20
ICA (isotropic conductive adhesive)	50 – 100	300 – 600
NCA (nonconductive adhesive)	150 – 180	5 – 20
Laser curing	150 – 300	<1

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Table 2. *Comparison of the flip chip adhesive joining processes.*

To better understand processing differences, Table 2 compares flip chip adhesive joining processes. For example, adhesive joining offers a reduction in interconnection temperature in contrast to soldering; however, adhesive joining has an increased dependency on the consistent performance of the materials used. In the process, the adhesive material accomplishes the actual interconnection and requires longer processing times to assure complete curing.

Advantages of Laser Curing

Because laser curing achieves a high temperature in a millisecond range time span, it provides advantages over thermode- and oven-curing processes using a range of substrate materials. Substrate materials used in today's flip chip applications are both rigid, such as FR4, BT-epoxy, polyimide, ceramic, TG, and silicon; and flex, such as polyimide, polypropylene (PP), and polyvinyl chloride (PVC).

The advantages of laser soldering and laser curing are based on the fundamental principles of laser physics. The short duration of the laser pulse induces a low thermal stress on the chip or substrate and interconnection because the thermal energy applied is significantly reduced, which in turn allows the implementation of newer, low-cost materials.

Method	Heating Time [sec]	Range [~]
Laser	0.01 – 0.1	msec.
Thermode	2 – 4	sec.
Reflow Oven	30 – 60	min.

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Table 1. *Reflow, thermode, and laser soldering times comparison.*

Laser flip chip attach technology is compatible with all known substrate and pad materials currently used in flip chip assembly. This is especially true for low-mass flexible substrates where the laser attach process - immediately and *in situ* - can solder devices on to the flexible substrate, reducing handling difficulties associated with surface mount device assembly on flexible materials by eliminating the reflow process and the required fixture assembly time.

Technical Advantages of Lasers for Assembly

The basic operational principles of lasers have made them ideal candidates for soldering and curing applications since the 1980s. Lasers offer compatibility with soldering and adhesive joining (laser curing) for flip chip attach; shorter soldering and adhesive curing times; compatibility with flip chip and resistor/capacitor attach; and indifference to substrate selection. Examples of demonstrated assembly advantages include: allowing bonding on low-cost/low-TG flex antenna materials; allowing bonding on rigid materials and a variety of metallizations; and are suitable for use with a range of different substrate metallizations.

The basic technology surrounding laser-assisted equipment enables higher throughput because the heating is done at the same time as pick-and-place and assembly reflow with an extremely short pulse -

less that a second - as placement occurs.

Ease of Implementation

Today's laser-assisted technologies are easy to implement. Equipment is available that incorporates the laser bonding directly in the bond head. An example of the typical process flow is shown in Figure 2.

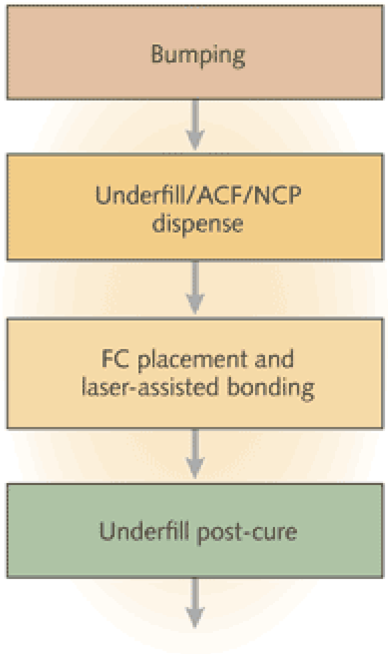

Figure 2. *Laser-assisted system process flow.*

As with other common assembly processes, the use of either a bumped die or a bumped substrate is required. The bumping processes suitable for use with laser-assisted equipment are shown in Table 3 and the technology is fully compatible with all standard industry processes.

Pad Metal	Al or Cu coated with Ni/Au, Sn, Au
Thin Film	Cr/Au, Ni/Au
Bump	Solder, Ni/Au*, Au* Solder cap: e.g. maskless meniscus bump (M2)

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Table 3. *Bumping and pad metallization requirements.*

Typical Applications

The most prominent use of laser-assisted equipment is in the manufacturing of flexible circuits on smart cards and smart labels. Figure 3 shows an application of smart label flip chip attached directly on an etched antenna and PVC substrate. However, alternative methods are possible. For example, the assembly can be performed on small modules, which are subsequently attached to the antenna. The module attachment approach allows a higher flexibility in the selection of the materials for the antenna in smart cards and smart labels.

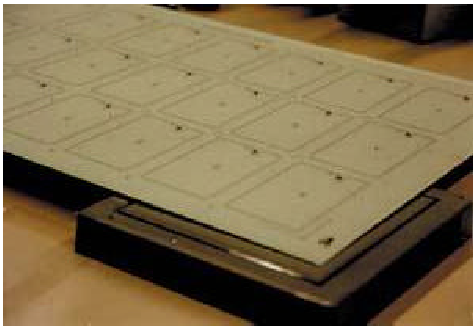

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Figure 3. *Flip chip on coil for contactless smart cards.*

Laser soldering can be used to selectively attach wire on bumped die for coils. It can also work with an adapted handling and pick-and-place tool for attaching small SMD components, such as resistors and capacitors, onto flex. In many consumer product applications, attaching resistors and capacitors cost-effectively is critical, and usually requires special fixtures. In contrast, laser attach techniques eliminate the need for special fixtures, because components are fixed and contacted by soldering or adhesive curing with a short pulse directly to the substrate during assembly. The high accuracy of laser-assisted systems and bonding pressure makes them ideal for LCD driver IC attachment because the bonding tools' accuracy is ±2.5 µm.

Ultra-fine-pitch (50 µm), low-cost electroless NiAu bumps can also be joined and interconnected to LCD devices, hard disc drives, etc. Low-cost bumps are produced with electroless Ni/Au under-bump metallization (UBM) and a solder cap of eutectic, tin-lead, lead-free, or AuSn solder. The small solder cap on these bumps eliminates the need for a soldermask, reducing substrate cost.

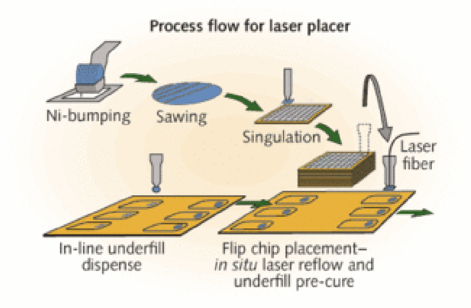

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Figure 4. *A laser placer machine process flow.*

Figure 4 shows a typical process flow for a laser placer machine. A dispenser is integrated into the product system for dispensing liquid such as underfill (e.g., no-flow underfill) or a flux for soldering processes.

For adhesive-joining processes, ACF or NCP can be used. Prior to dispensing, a preheating stage can be integrated into the system to remove humidity during the flip chip attach and curing process.

The chips can then be picked from waffle packs or a direct die feeder that uses the sawing film. The laser optics tool is integrated into the bonding tool, which uses vacuum to pick up the chips. The laser heats the silicon die from the backside, inducing thermal energy to either make the interconnection between chip and substrate or to cure the adhesive, allowing the laser to be used both for soldering on one side and for curing of the adhesive underfill material using an ACF, NCP, or other suitable material.

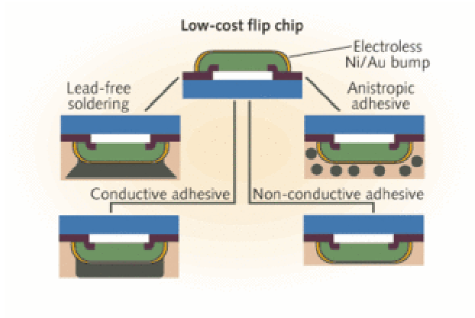

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Figure 5. *Low-cost flip chip technologies.*

Several laser joining interconnection technologies are compatible with flip chip applications (Figure 5), including electroless Ni/Au bumping, lead-free soldering, anisotropic adhesives, conductive adhesives, and non-conductive adhesives. Alternatively, laser soldering can be used for selective attach of wires on bumped dies for coils to attach an IC.

Conclusion

Because of its ability to concentrate large amounts of energy in a small space for short durations, laser technology is well-suited to meeting the demands of some of electronic interconnections' most daunting challenges, especially those associated with flip chip and direct chip attach. Additionally, that same ability can be applied to the rapid thermal curing of materials, such as underfill, commonly associated with flip chip assembly. Given the rapid maturity of the laser soldering technology, it is expected to see substantial growth as manufacturers more fully realize and comprehend the advantages for present and future interconnection applications.

References

Contact the authors for a complete list of references.

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