Are separate solder flip-chip bonders still required?

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Increasing miniaturization is now encouraging manufacturers of handheld devices to stack bare dies or packages. As the process of manufacturing modules requires placing both passives and (stacked) bare dies, these two types of placements are merging very quickly into a single platform. That raises the question of whether SMT equipment will take over from traditional die bonders.

The relentless drive to reduce equipment size has already led to successive generations of miniaturized components, while passive components have been steadily integrated into ICs and packages. The next step is to free up even more PCB surface area by embedding passives into the PCB substrate rather than placing them on the surface.

The steep increase in electronic functions meanwhile requires an ever increasing number of I/Os on the same footprint, leading to a whole new generation of ICs (Figure 1). Trends like Wafer-Level Packages, Through-Silicon Vias and embedded passive and active devices are reducing the need for traditional wire bonding, which is slowly but steadily being replaced by flip-chip bonding.

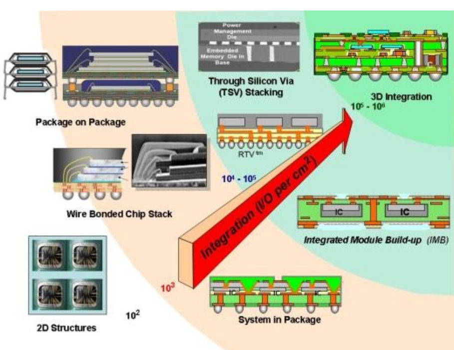

Figure 1: Roadmap for number of I/Os per area: Source: Happy Holden, MIPBG-Foxconn, DaYuan, Taiwan

SMT pick & place equipment has already moved into the back-end semiconductor market with advanced hybrid assemblies (Figure 2), where passives are mixed with bare-die products in assemblies such as Modules, Single In-line Packages, Package on Package, Multi-Chip Packages and MEMS devices. Die (flip-chip) stacking is the next major step into back-end semiconductor manufacturing, and work done by Assembléon has shown that pick & place machines can take over from die bonders in many applications.

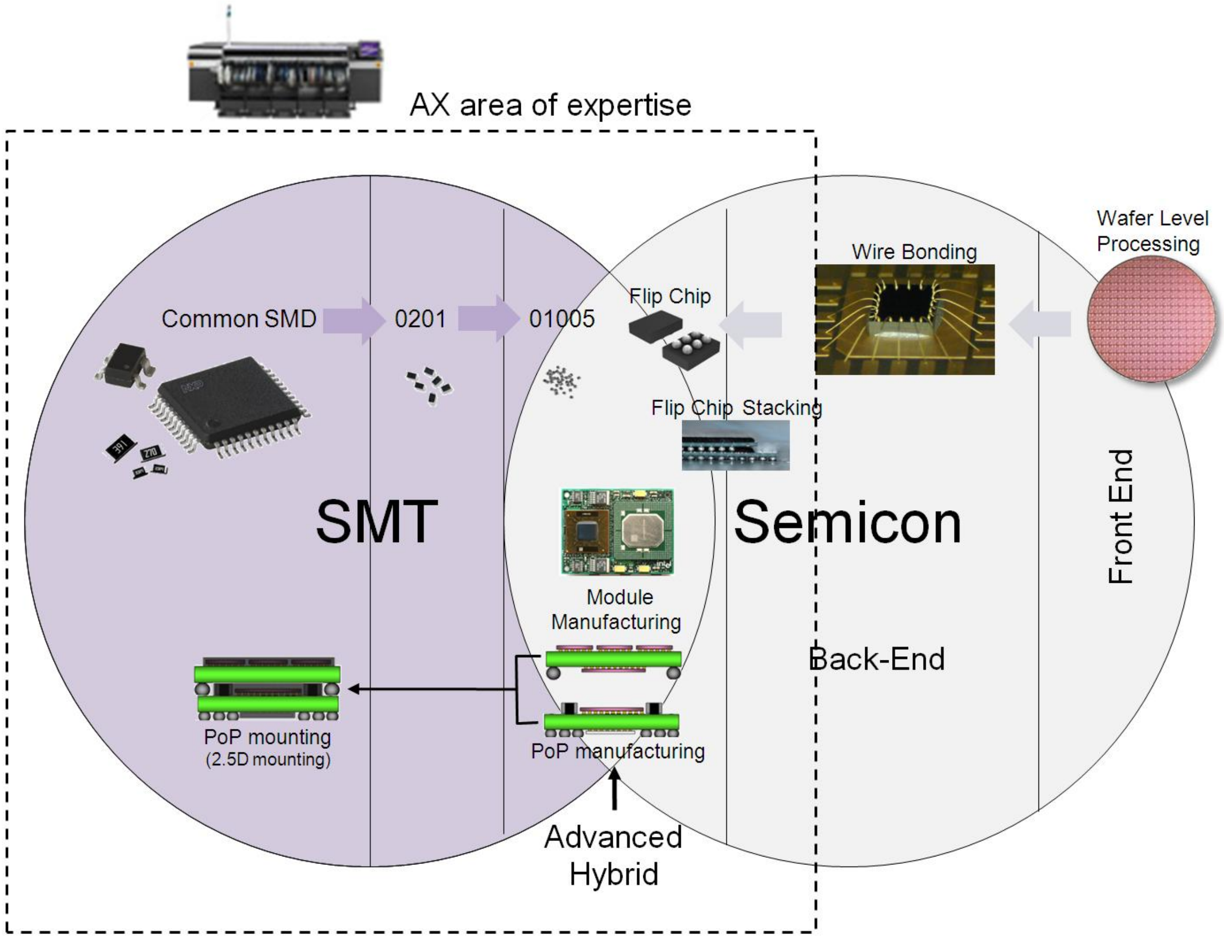

Figure 2: Advanced Hybrid Assembly

SMT equipment moving towards bonding rather than bonders moving to SMT

Most die-bonding operations are today done by specialized and relatively slow bonders with limited SMD capabilities. The need for tighter interspacing, increased accuracy and embedding of both passive and active components has brought an increasing demand for traditional SMT equipment to place dies accurately. This is seen as a natural next step for SMT equipment, rather than bonders making a step towards higher volume SMD placements. The move is underlined by the increasing market share of flip-chip bonding – now approaching a quarter of the bonding market (Table 1).

Bonding type	2006	2010	2013F
Wire bonding	83%	79%	76%
Flip-chip bonding	17%	21%	24%

Table 1: The trend is from wire bonding to flip-chip bonding: Source Gartner

Taking on the die-stacking challenges

With bump sizes now below 100 µm and placement forces down to 0.5 N, many traditional SMT placement machines need to adapt to take on die stacking. Similarly, bare-die placement accuracies are heading towards 10 µm, while 40 µm is more than sufficient for traditional PCB assembly. Many placement designs also fall short of the high speeds that are needed, and cannot be adapted that easily – or at all. Assembléon's continually improving single pick, single place concept however has all the basics needed to move into the market. The A-Series equipment already has an established reputation for its accurate, repeatable and error free placement of miniature components such as 01005, 0201 and flip chips, even within embedded substrates.

The AX system has been built to evolve with new technologies, and Assembléon has recently introduced a new linear Twin Placement Robot (TPR) for its existing AX-501 and AX-301 machines. The robot improves accuracy to 10 µm while maintaining speed and full process control (see Figure 3). Additionally, Assembléon has introduced new linear dip stations that add a controlled dip process near where the die is placed on the substrate. The dip station can handle flux (generally for bump sizes below 100 µm) or paste (for bump sizes above 150 µm) at various depths to match specific bump size requirements.

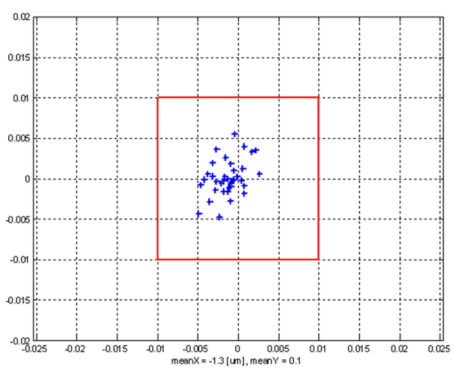

Figure 3: Assembléon's 10 micron 3 sigma@Cpk>1 TPR placement accuracy

More value in the package

With the increasing number of I/Os per package, the value of integrated packages is also increasing. That adds another important variable to the equation: quality of manufacturing. High placement quality of *known good dies* is therefore a must as undetected errors will eventually end up in the final package and, once packaged, there is no chance of repair.

Assembléon's A-Series (Figure 4) is the only pick & place machine that can achieve single-figure defect per million quality levels – now in fact down to 5 dpm. Its unique parallel placement system, with all robots having a single head and a single nozzle, gives full process control for each individual package. That is the basic process required to step into accurate, repeatable, reliable and high volume flip-chip placement.

Figure 4: Assembleon's AX-501 with Twin Placement Robot

Closed-loop controlled die stacking

There are two parts to the dip action and placement force (just called 'placement force' in the rest of this article): the first is the moment of impact, followed immediately by a dwell placement force. Placing and dipping bare-die components (Figure 5) demands very low, accurate and stable placement forces that go down to 0.5 N (but check bare-die product vendor specifications). Spike forces need to be kept as close to zero as possible.

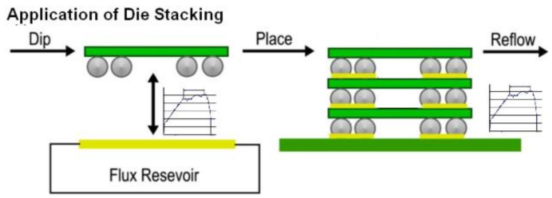

Figure 5: Application process – dip, then place/stack**.**

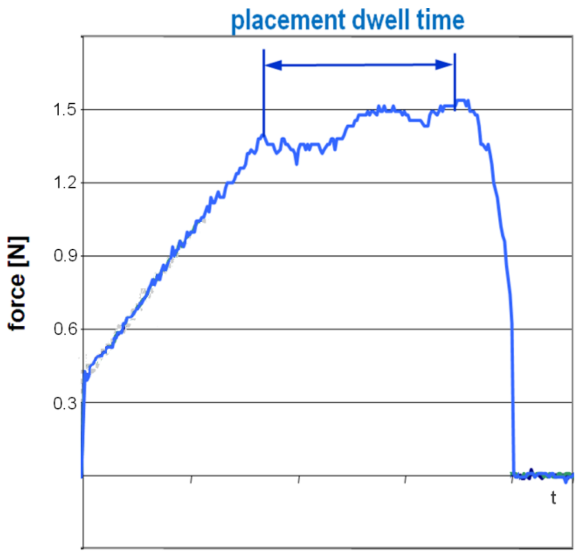

Figure 6: The moment of impact is followed by a dwell placement force

Figure 6 shows the closed-loop active placement force control of the A-Series, which delivers the required placement dwell and forces regardless of component type, substrate type, condition of substrate, and transport system. On an A-Series machine, the placement force is dynamically monitored using a closed loop system integrated into the placement head. The system also ensures that there is **no** spike force upon impact, with the force instead being built up towards the required dwell force (also known as static force). While the A-Series currently only measures from 1 N upwards (SMT now requires a minimum of 1.5 N), low-impact force nozzles allow the process to apply any force below 1 N (e.g. the 0.5 N mentioned above).

Rotary and linear dip stations

The two commonly used dip stations are the rotary and the linear types. The first uses an adjustable squeegee to maintain flux height while the second has plates with flux chambers having a pre-defined depth. Although the end results of both are the same, it can be said that over time the linear type (Figure 7) is less sensitive to maintenance, and provides a fixed and constant flat flux/paste surface. It therefore gives a better guarantee of even paste/flux application per bump. Additionally, when process parameters are fixed and production volumes are large, the linear type is generally preferred over the rotary type. The reason is a fixed and easy setup, guaranteed dip depth, easier maintenance and easy handling by standard operators. With smaller batch sizes or prototyping with many variations in flux depth, the rotary type is more suitable.

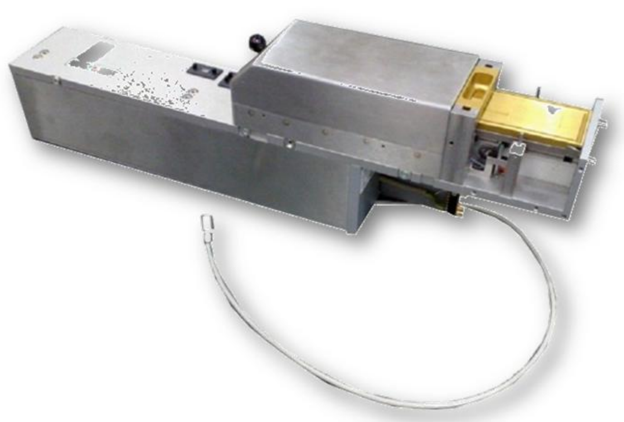

Figure 7: Assembléon's linear dip flux station

A general guideline for the required flux depth is to use 50% of the bump height (Figure 8), avoiding either insufficient or excessive flux.

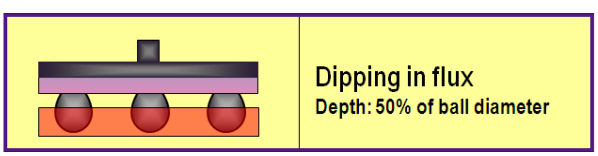

Figure 8: Guideline for flux depth

Releasing the component from the dip station (the component's surface should be perpendicular to the equipment's toolbit) is a controlled movement. It should avoid the forming of strings (Figure 9) or uneven flux which may cause bridging or other defects during reflow.

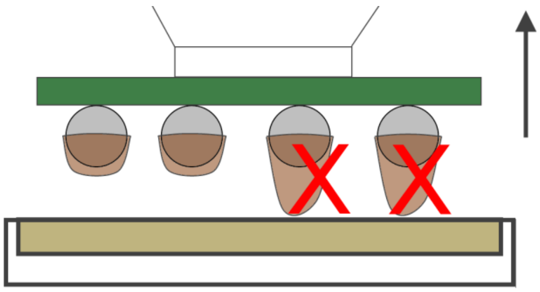

Figure 9: Controlled up-movement to avoid stringing of flux

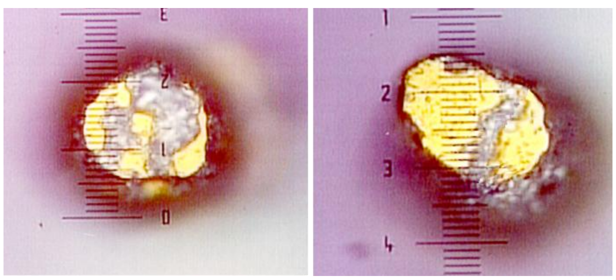

Figure 10: Applied flux (yellow); left: too less flux ; right: sufficient flux

Figure 10 shows the effect of a short and insufficient flux depth. By increasing the dwell time, deceleration and acceleration speed and adjusting the flux depth to 50% the device had sufficient flux applied to the Au-stud bumps (right-hand image in Figure 10).

Controlled stacked placement

During the first part of a placement action, the Z-axis of the placement head moves downwards at high speed. When it arrives at the 'search zone' (which is increased during stacking), the speed is reduced to the search speed (Figure 11). The downward motion then continues until contact with the board, substrate, or previously placed bare die is detected.

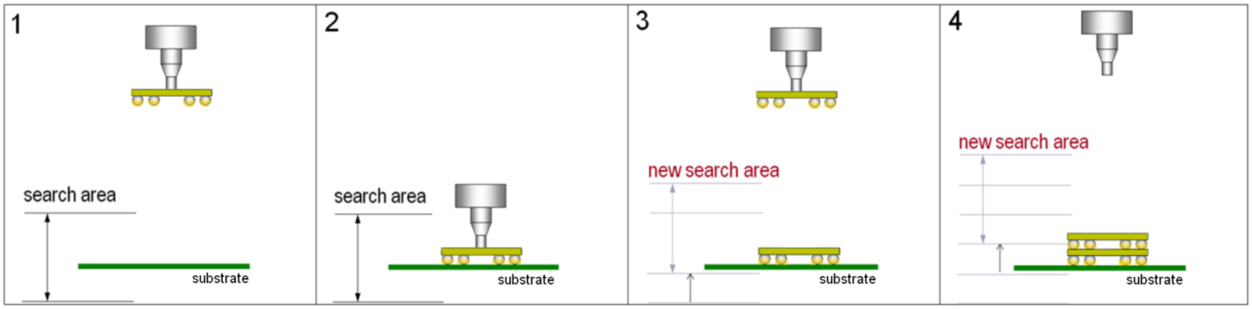

Figure 11: Stacking and adjustment of search area

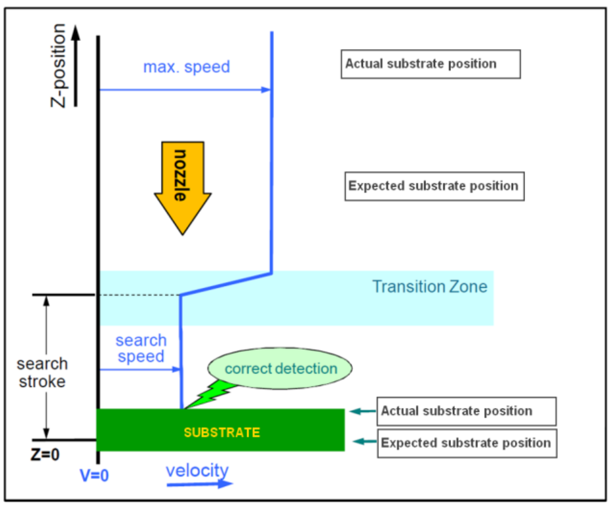

Figure 12: Correct detection of contact with the substrate

The advanced collision detection mechanism (Figure 12) filters out any false collision signals but always ensures that a component is placed. Throughout its lifetime, the system records all placements and alerts the operator of behavior which may influence placement quality – a requirement when board/substrate quality is critical.

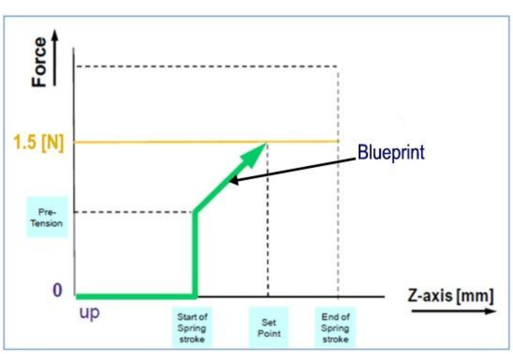

Figure 13: Comparing placement against a blueprint value

To ensure reliably low and stable placement forces, Assembléon's pick & place process not only measures the force using the real-time and closed-loop placement mechanism, but also compares it against a blueprint value – a placement profile description (Figure 13). Monitoring systems check whether the bare-die product has been detached from the nozzle tip immediately after placement. This quality check filters out any behavior that does not meet the blueprint value and warns the operator in time, avoiding possible costly package waste throughout the machine's lifetime.

Assembléon's AX-301/501 pick & place system

Assembléon's pick & place process is widely used at the world's leading back-end, automotive, embedded and electronics manufacturers. All have very high quality requirements, and successfully place trillions of challenging miniature components at very high yields.

Assembléon's new Twin Placement Robot is capable of placing bare dies at 10 µm and CpK>1 , with outputs up to approximately 4.5 kcph per TPR. Both TPR and standard robots can also place standard passives and actives dust free at the same process quality levels, making the A-Series all-in-one machines for packages incorporating both SMD placements and die stacking.