

Odd-Form Factor Package Wire Bond Case Studies

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Abstract

Although there is continued effort in the semiconductor packaging industry to reduce package size along with the never ending pursuit of cost savings, there remain a significant number of applications which require a wildly different set of capabilities for wire bonding. This paper will explore the wire bonding requirements of several device cases that could be considered odd form factor package formats when compared to mainstream semiconductor packaging. Example cases are presented to show the challenges and solutions to wire bond packages in the RF, Automotive, and Optical markets with large form factor (12inch x 6inch), deep reach (0.535 inch), leads, pins, and other challenges.

Key words: Wire Bond, Large Area, Deep Access, Hybrid, SIP, MCM, RF, Optoelectronic, Optical, Automotive

Background

Motivation for the work is to reduce customer's cost of ownership to produce automated ball bonding for non-standard, odd-form factor packaging applications.

Odd-Form factor applications have significantly different inputs and requirements than typical semiconductor packaging applications. Table 1 lists the primary characteristic differences between semiconductor and odd-form factor wire bonder requirements. The work area range in XY and the Z axes are significantly different between the two types of machines. Semi machines typically use a hitch feed style handler to pull segments of the parts into position for a limited bonding area while the large workspace of the odd-form style machine can bond all of the parts in a 6inch by 12inch area in one pass.

The primary difference in input packages is easily seen when comparing Figure 1 and Figure 2. The semiconductor package formats are designed as strip like format for ease of handling in magazines and in-line conveyors. Odd-form packages for optoelectronic, RF, and other miscellaneous applications differ greatly in their shape and size. Additionally, they can have a single die or hundreds of die in the same package. With a large number of parts and part types in the same package, the odd-form wire bonding machine

software must allow the flexibility to have parameter sets for multiple bond surfaces and loop profiles. Programmable focus allows the odd-form wire bonder machine to reference and bond across a wide range of bond surface heights as shown in Table 1.

Table 1 – Semi versus Odd-Form Wire Bonders

Characteristic	SEMI [1]	ODD/Hybrid [2]
Machine Price	Lower	Higher
Machine Throughput	Higher	Lower
Package Formats	Leadframe Strip	RF, Optoelectronic, Automotive, Defense, Other
Part Presentation	Leadframe Strip Boat	Tray Boat Custom Fixture
Machine Feed	Mag-Mag	Mag-Mag In-line Manual Batch
Work Area XY	2.2" x 3.1" 56mm x 80mm	6"x12" 152.4mm x 304.5mm
Bondable Depth Z	~0.100" Tilt Z 2.54mm	0.545" Linear Z 13.8mm
Features	Programmable optics with a full 2.5mm focus range	Programmable Focus with 15mm focus range

Odd-Form Case Examples

Three specific examples are provided below to highlight the primary challenges and solutions in odd-form package assembly, requiring capabilities significantly beyond conventional semiconductor wire bonders.

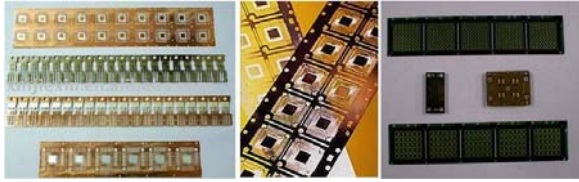


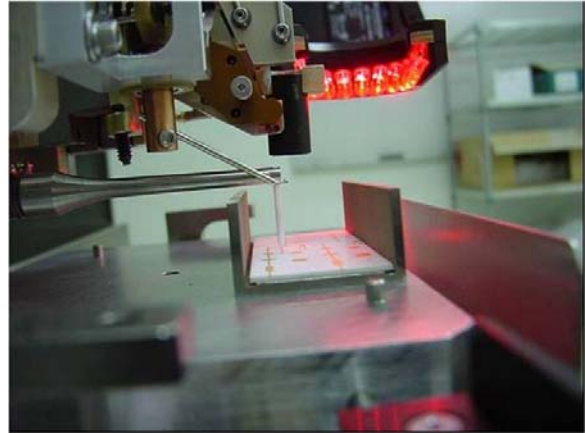
Figure 1 – Semi format input materials



**Figure 2 – Odd-Form Material Inputs
(Boat or Trays not shown)**

Case 1: Deep Access 0.535"

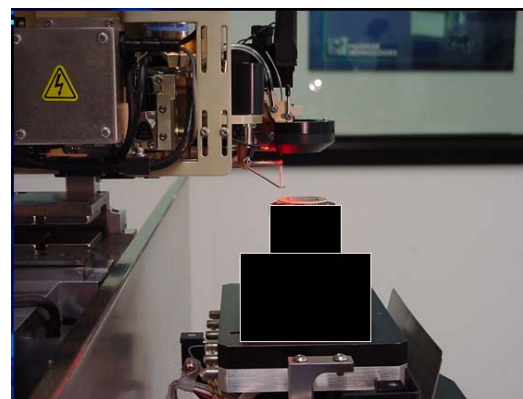
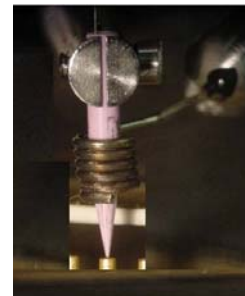
The specific case in Figure 3 is an example of a part requiring 0.535" of deep access to bond wires on a substrate previously attached to a heat sink. Although it could be debated that wire bond could be done prior to substrate attach to heat sink, this case required two substrates be wire bonded together after substrate attachment into the heat sink. Achieving the bonding access required a 0.750" capillary with the EFO wand adjusted slightly above the top of the heat sink. This particular wire bonder uses a linear Z axis to move the ultrasonic transducer, wire clamp, and optics through the >0.800" of Z range, significantly beyond the range of a semiconductor wire bonder. This setup allows the machine to use programmable focus for the substrate referencing.



**Figure 3 – Deep Access of 0.535" using a
0.750 Capillary**

Case 2: Ambient Wire Bonding to a 6" Tall Package

This specific case in Figure 4 is an example of a 6" tall part that is bonded at ambient temperature. The part required ambient bonding because of heat sensitive components plus it was impractical to get heat from the part base up through the entire 6" of length. A tool heater wrapped around the capillary is used to create the extra activation energy for bonding as shown in Figure 4a. The tall part is shown mounted on the wire bonder in Figure 4b.



**Figure 4 – Ambient Pin to Substrate Bonding on 6"
tall part: A) Tool Heater,
B) Tall part on mounting stage**

The wire bonder machine in Figure 5 has a flat plate of ¼-20 screw holes for mounting and adjusting tool stages to present a 6" tall part into the proper bond zone. Bonding a thin or thick part only requires moving the stage in the Z axis as shown in Figure 5. Dual pyrometers for conductive heater plate and convective radiant tool heater are available. In this case the tool heater was used since the part could tolerate heat.

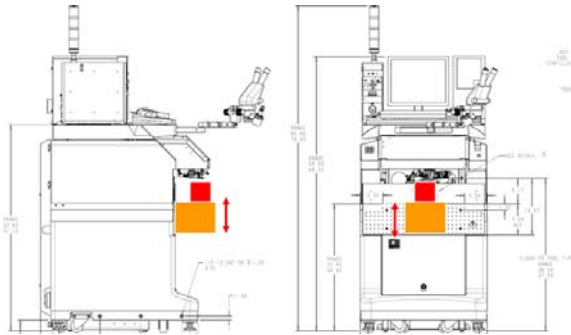


Figure 5 – Mounting Stage on Adjustable Plate

Case 3: Batch Load Tray (Mechanical and Vacuum Clamping)

In this case, a customer has a wide range of odd-form packages that they manually load/unload onto a wire bonder. The batch load system in Figure 6 is used to improve throughput and efficiency. There are two classes of parts that require either mechanical or vacuum clamping as shown in Figure 6A or 6B respectively. Vacuum clamping is used to minimize tooling complexity where possible. However, there are cases where mechanical clamping is required to hold the parts. In both cases, trays full of parts are manually manipulated with a detachable handle. The handle locks into position and isolates the operator from heat. Each tray type has a mating heated base that is mounted to the bonder heater stage. Switching from one part type to another is accomplished by changing the base plate and loading another program on the bonder. Tooling is designed to minimize change-over time by ensuring that no adjustments to the EFO wand are required.

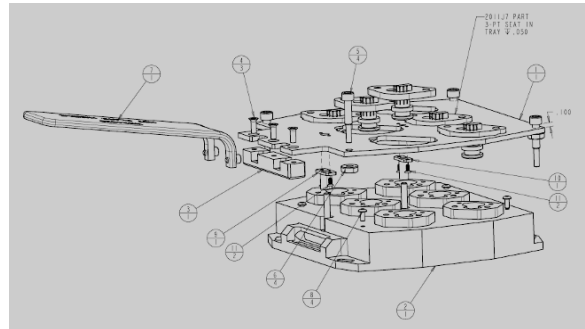
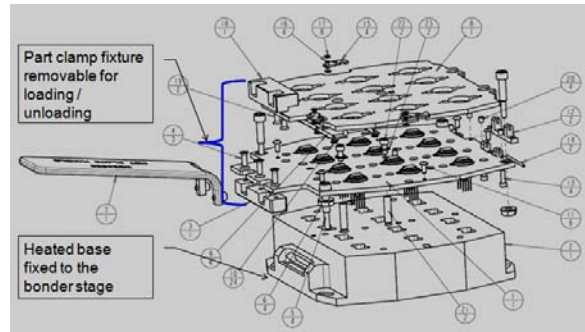


Figure 6 – Batch Load Trays with matching Heater Bases: A) Mechanical Clamp Tray, B) Vacuum Tray

The large XY area in odd-form wire bonders can support two stages as shown in Figure 7. This allows batch loading of many parts for bonding.

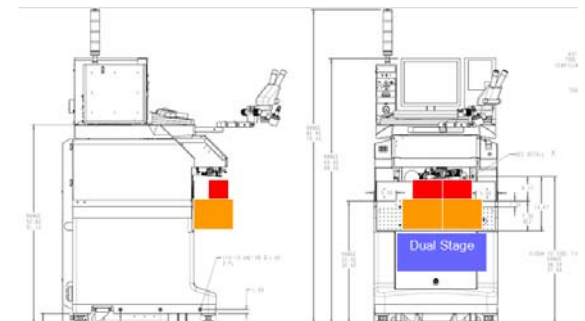


Figure 7 – Dual Stage for Batch Load

Misc Cases: Automated Handling

Moving beyond batch loading of odd-form parts requires adding automated material handlers to the bonder by removing the manual stage and then attaching the appropriate handler. Handlers are available for standard 3.1", 4.3", and 5.4" by 12" boats. Handlers to support custom pallets and lead frames are available. Corresponding boat magazines and magazine handlers are also available to support these boats as shown in Figure 8. Since the system is SMEMA [3] compatible, the magazine handlers can be moved up or down stream and the bonder inserted between other SMEMA compatible equipment in a production line.

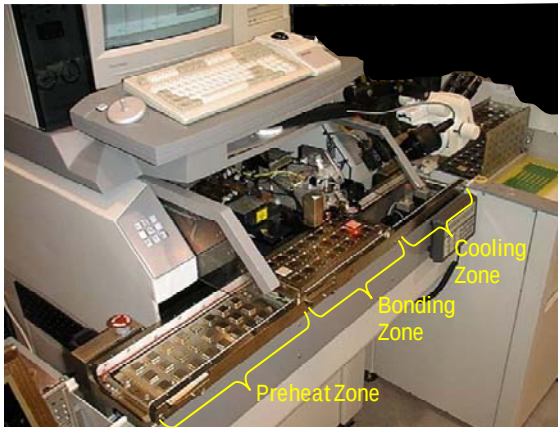


Figure 8 – Automated SMEMA Compatible boat handler with preheat, bonding, and cooling zone plus magazine input and output

Highly customized material handlers are also possible as shown in Figure 9. These systems are built to specification based on the odd-form part. The system in Figure 9 is a system for automotive parts that required heat soaking the parts before presentation to the bonder.



Figure 9 – Through Conveyor system with odd-form part

Odd-Form Wire Tools

There are series of wire bonding tools that allow handling the range of challenges seen when bonding odd-form parts.

Stand-off stitch (SOS) and Security Bond (SB) shown in Figure 10 provide examples of using bumps or wires in combination with other wires or bumps. Using a bump under a stitch is not only useful for die to die bonding as in SOS.B but can also be an effective means to bond a stitch to a poorly bondable substrate as in SOS.A. Bumps can also be used to bond to pins (horizontal or vertical) as shown in SOS.C. Some high reliability packages can also require security bonds as shown in Figure 10 (SB).

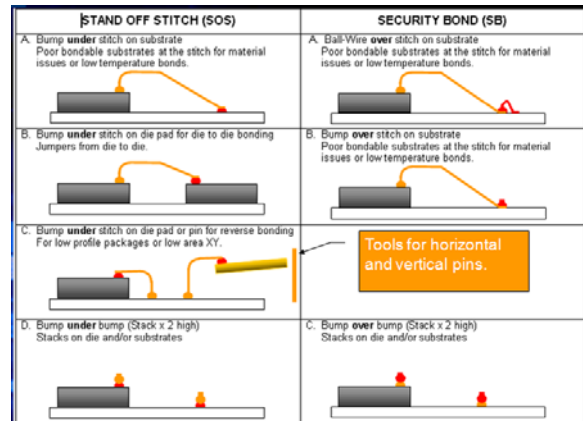


Figure 10 – Odd-form Wire Bond Tools A) Stand-off Stitch, B) Security Bond

Additional wire bonding tools such as chain bonding technology can also be combined with stand-off stitch and/or security bond technology as shown in Figure 11. A Chain bond begins with a standard ball bond and loop but with a modified stitch which does not cut through the wire. That stitch is then followed by another loop and stitch and etc. Ultimately, the final stitch in the chain is terminated to form a tail and free air ball for the start of the next chain.

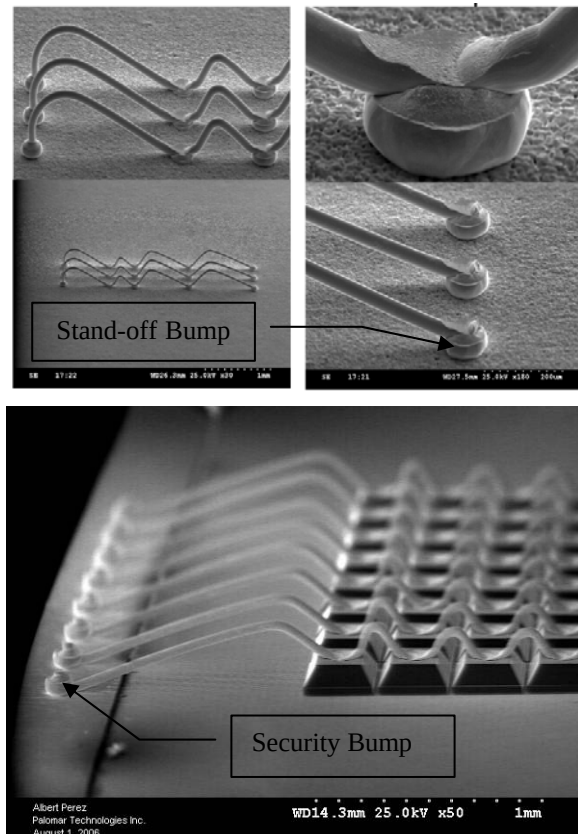


Figure 11 – Chain bonds with stitches on stand-off bumps and stitches covered with security bumps

Stand-off stitch can be used to change geometry of the loops or improve bonding on difficult surfaces. Chain bonding can also be combined with a security bond on the terminating stitch. The security bond can be a ball bump (shown) or ball-loop-stitch.

The **RFSOE Power Transistor** is typically bonded with wedge bonder technology. Here a ball bonder can effectively replicate a chain of wires like in wedge bonding. The chain wire bonds in Figure 12 show different loop shapes in the same chain starting with a ball bond at the highest surface then bonding an intermediate stitch at the lowest surface and then a terminating stitch at another surface height. Small jumpers are then bonded from die to die.

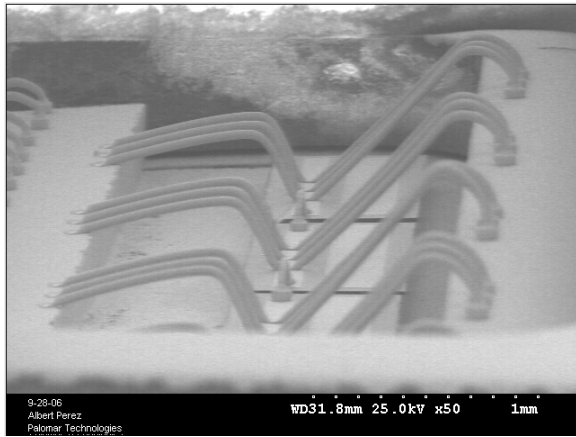


Figure 12 – RFSOE chain wire bonds

Chain wire bonds in Figure 13 show a more densely populated set of chain wires compared to Figure 12. Some of the chain wires go left to right while others go right to left. They all span different surface heights and materials. Some of the chains contain ultra-low loop heights as well. The wire bonder software must have flexible control of the order of bonding and allow different bonding and loop parameters for each of the surfaces and loop segments to create this interconnect pattern.

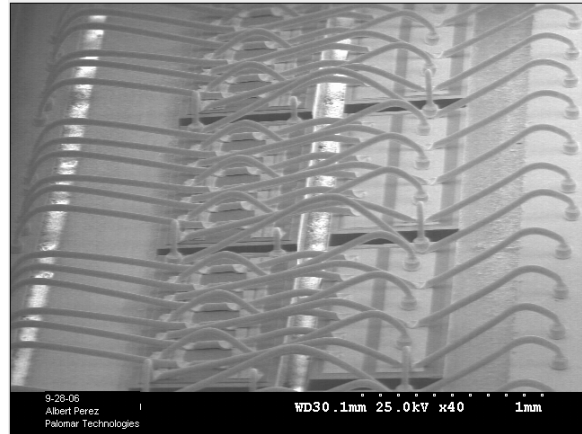


Figure 13 – RFSOE chain wires show loop control and sequence order control

Summary and Conclusion

The purpose of this paper is to show the differences in parts and capabilities between semiconductor and odd-form factor part (hybrid) wire bonding machines. The dramatic difference is the input part types shown in Figures 1 and 2. Odd-form factor wire bonders in this paper have larger work space and handle a wider range of part sizes. However, they are typically more expensive and have lower throughput when compared to semiconductor package wire bonders. But many odd-form packages simply cannot be bonded on semiconductor bonders.

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