Improved Bond reliability through the use of Auxiliary Wires (Security Bumps and Stand-Off Stitch)

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Abstract

Whether the need is due to poorly bondable materials, non-flat bonding surfaces, odd packaging situations, or just the need for high reliability; the integrity of a wire bond interconnect can usually be greatly improved through the proper use of Auxiliary Wires. Auxiliary Wires are defined as Security Wires, Security Bumps, or Stand-Off Stitch (aka Stitch on Bump). The old stand-by Security Wire has been an asset for several decades, however, this is being replaced by Security Bumps which require a smaller second bond termination area. Further, Stand-Off Stitch (SOS) has many more applications and also has many side benefits that could be incorporated into a circuit design for better wire strength properties, fewer interconnects (die to die bonding), and lower loops. Stand-Off Stitch bonding involves the placement of a ball bump at one end of the wire interconnect, then placing a wire with another ball at the other end of the interconnect and stitching off the wire on the previous placed ball bump. This results in a near homogeneous stitch bond interconnect to the bump with an inherent improvement in stitch bond pull strength. Another use for SOS is Reverse Bonding (Stitch bond on bump on die bond pad) often resulting in a lower loop profile than standard forward wire loop and the loop is stronger because the wire hasn't been work annealed above the ball (in the Heat Affected Zone). A major impediment to the implementation of SOS is the retraining of visual inspectors and the approval of quality departments.

Key words: Wire Bond, Reliability, Hybrid, Military, Biomedical, Optoelectronic, Optical, Automotive

Introduction

Since the early days of wire bonding we have been searching for ways to improve the wire bond interconnect strength and reliability. Whether it is for a critical biomedical device, the latest spacecraft or military weapon system or just your new big screen TV at home, we try to assure that EVERY interconnect we make is secure. We have to deal with marginal materials, but still ensure a reliable interconnect. We have adjusted wire dopants to improve crystal structure in the Heat Affected Zone, allowed for various loop modes which put (sometimes extreme) stresses on the wire, and to reduce the likelihood of the formation of intermetalic contaminants. What remains as the weakest link in most cases is the stitch bond.

Motivation for study

Improve Wire Bond Interconnect Reliability

- Increase Pull Strength of Stitch Bond
- Improve Failure Mode from Destructive Pull Test (more Mid-Span and Neck Breaks than Tail Breaks even with Poor Materials)
- Improve Bond Strength after High Temp Burn In

Figure 1 below shows various ways to use Auxiliary Wires in gold ball bonding. The earliest attempt to improve stitch bond strength was the Safety Wire or Security Wire (fig 1, right A), where an extra wire was formed with the ball placed on the crescent bond of the primary wire and then itself stitched off nearby. As densities have increased there is now much less real estate to allow for this approach. Hence the current use of Security Bumps (fig 1, right B), where a Ball Bump is placed on the crescent bond.

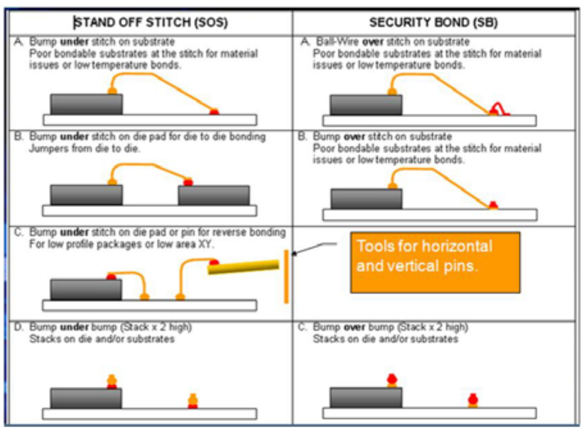

Figure 1 Various Auxiliary Wire options available on the Model 8000 bonder.

The resulting bond is generally stronger than without the Bump; however, the process of bonding the bump on top of the wire does not produce a completely homogenous interconnect. There can be boundaries at the bump/wire interface and at the bump/substrate interface (fig 2).

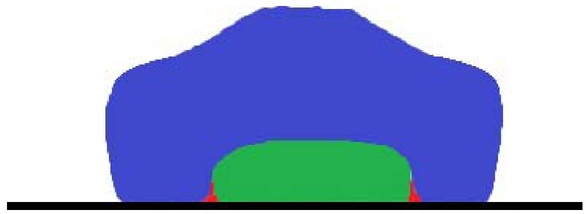

Figure 2 Possible problem areas in RED.

The most successful approach we have found so far is the Stand-Off Stitch bond (fig 1, left A-C). This is formed by first placing a Ball Bump at the stitch bond location, then forming a normal wire from the first bond location to terminate on top of the previously placed bump. Forming the stitch bond on the bump does provide a nearly homogenous interconnect (fig 3).

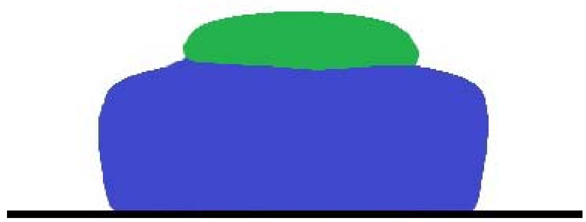

Figure 3 The entire lower surface of the bump is bonded to the substrate and the entire stitch is bonded to the top of the bump.

There are other advantages to this process including the ability to place the second bond on the die without damaging the die by stitching off directly on the die bond pad (and a violation of Mil spec 883) (fig 1, left B). This has allowed for unique packaging solutions that were otherwise unavailable such as closely spaced die with die-to-die wires (with no substrate interconnect) and stacked die with obstructive walls very near the bond pad location.

Another application is to improve the bond strength on difficult to bond to materials which can lead to stitch lifts and operator assists due to flame-off errors. Goodrich is using 10 micron thick Aluminum on Quartz in some of their products. The soft Aluminum and hard Quartz make it difficult to achieve a reliable and strong stitch bond directly to the Aluminum. It is, however, relatively easy to get a strong bond with the larger surface area of the ball bump.

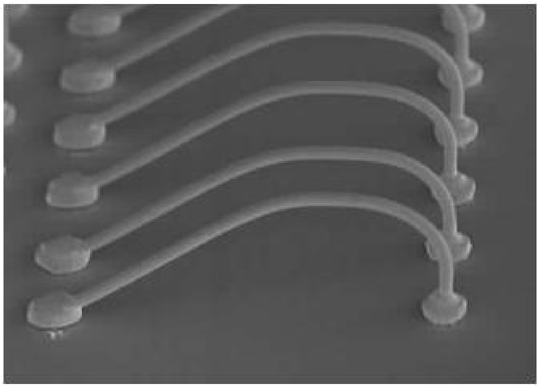

Figure 4 Simple example of Stand-Off Stitch wire where the stitch bond is placed on a previously placed ball bump.

Goodrich uses this process now on most of their products. They have found 3 distinct and measurable advantages to using Stand-Off Stitch when compared to Security Bumps.

1. Higher destructive pull test values after 125°C burn in with the Stand-Off Stitch process.
2. Increase in the percent of failures as Code 2 (break above the ball) and Code 3 (mid-span break in the wire) in destructive pull test using the Stand-Off Stitch. This shows that the failure mode during destructive pull test is in the HAZ or bulk properties of the wire and not the bond interface for the Stand-Off Stitch process.
3. Improvement in wire bond reliability when wire bonding gold bonds on aluminum pads using the Stand-Off Stitch process. This improvement in wire bond reliability can be seen using the MIL-STD 883 Method 5008 test. This 300°C bake prior to destructive pull test is intended to screen weaker bonds. The results show the wire bond strength of the Stand-Off Stitch process do not degrade after being exposed to 300°C for one hour while the Security Bond process bonds do degrade.

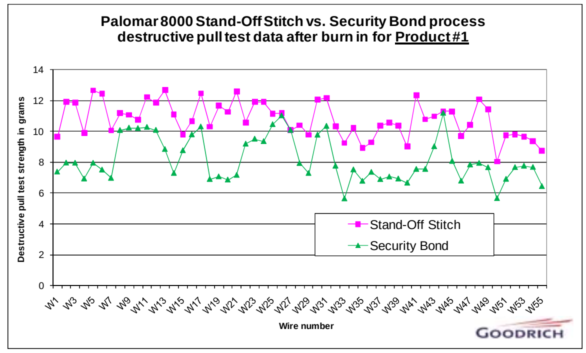

Figure 5 Improved pull strength an average of 30% with SOS over Security Bond after 125°C burn in – Product 1.

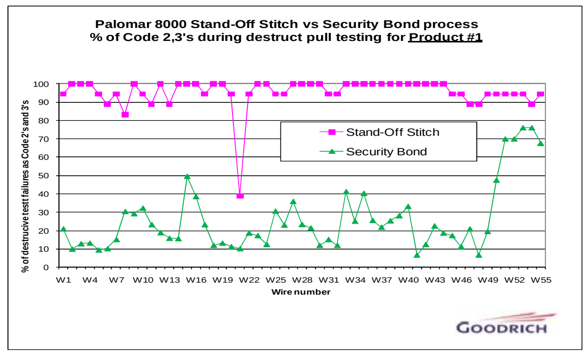

Figure 6 Improved failure mode with SOS over Security Bond – Product 1. This seems counter intuitive, but the bump placed over a wire indeed does produce a weaker bond with breakage at the wire bump interface.

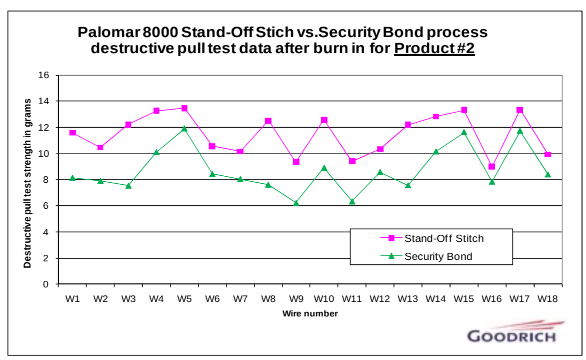

Figure 7 Retained Destructive pull advantage after 125°C burn in – Product 2.

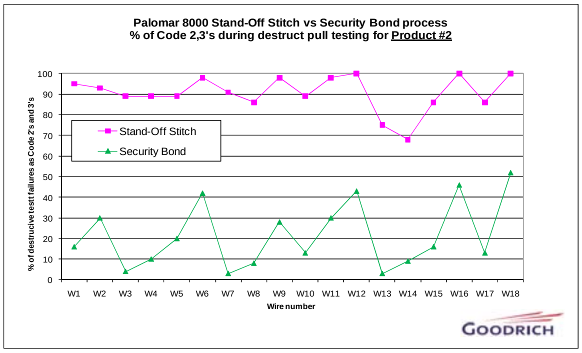

Figure 8 Improved failure mode on second product after 125°C burn in – Product 2.

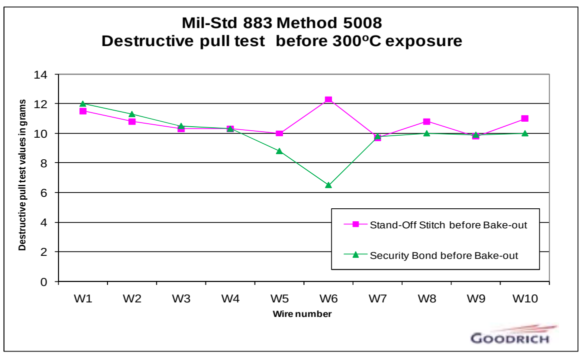

Figure 9 Product 3 - even on a product with similar pull strength before burn in...

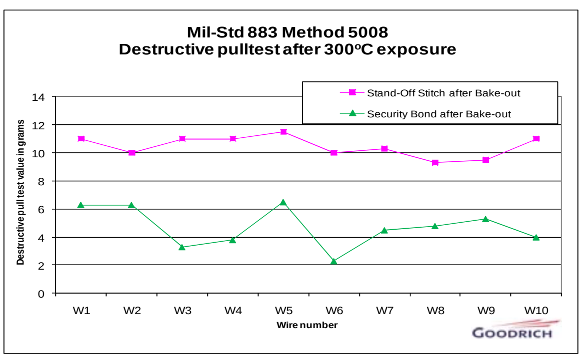

Figure 10 Has retained higher pull strengths after 300°C burn in – Product 3.

Other benefits Goodrich has experienced using the Stand-Off Stitch process:

1. Wirebonding complex packages sometimes requires bond pad locations near physical obstructions that traditional ball and stitch forward bonding could not accomplish. The Stand-Off Stitch gives the flexibility by using reverse bonding to place wirebonds near physical obstructions. Traditional forward bonding would not allow wire formation due to the proximity of the wall.

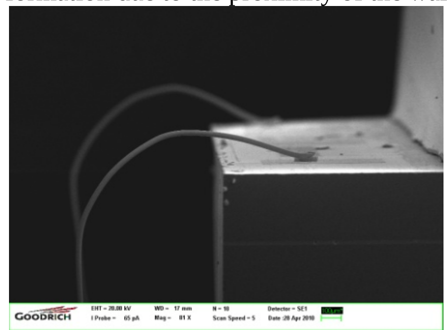

Figure 11 Stacked die obstructs tool path to form forward bond from die - reverse bond with Stand-Off Stitch required.

2. Stitch bond on delicate die using Stand-Off Stitch process. The Stand-Off Stitch process allows the stitch to be bonded on delicate component die pads by providing a large gold bump to bond the stitch on top of preventing the capillary tool from damaging the die pad during the stitch bond. This allows wirebonding a product that could not be otherwise reverse bonded without the Stand-Off Stitch process.

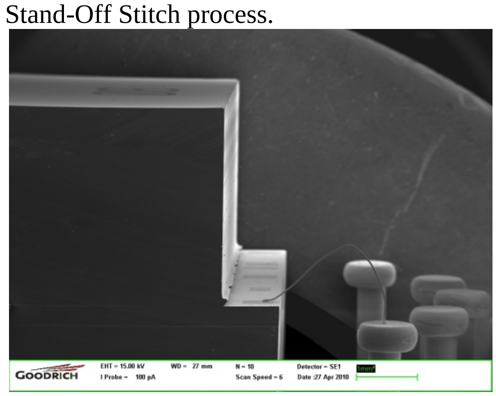

Figure 12 Delicate die on left requires Stand-Off Stitch for reverse bond interconnect.

3. Improve wirebondability of difficult to bond materials by using Stand-Off Stitch. The first requirement for high yield bonding is a clean bondable pad material. Often times the subsequent processing reduces this bondability of the pad to the point that the wires no longer stick to the pad. The stitch is usually weaker (or has a more difficult time sticking to the pad) than the ball due to smaller bond surface area. The Stand-Off Stitch provides a robust bond by having the larger surface area of the ball bond on both ends of the wire significantly improves the wirebond adhesion to the poor material.

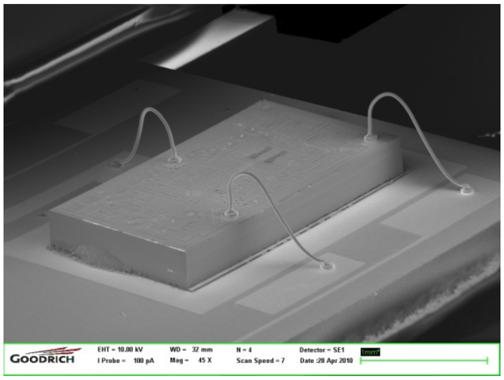

Figure 13 Ten micron Aluminum on Quartz provides poor bondability for stitch bond.

Conclusion

This study demonstrates that the Stand-Off Stitch process provides improved stitch bond interconnect reliability with many other advantages for advanced packaging processes such as die-to-die wires, tight package geometries and the use of difficult to bond to materials.

Biographies

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David has over 30 years experience with wire bonding from the equipment manufacturing side and is currently an Applications Engineer for Palomar Technologies.

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Rodney received a B.S. in Mechanical Engineering from the University of Minnesota Institute of Technology in 1988. He joined Goodrich in 1989 and is currently a MEMs manufacturing process engineer with Goodrich's Sensors and Integrated Systems Division.

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