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TECHNOLOGIES

Modern Wedge Bonding eBook

MAKING THE CONNECTED WORLD POSSIBLE

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Brief History of Wire vs. Wedge Bonding

The first wire bonder was designed in 1957 and was a thermocompression wedge bonder. Ultrasonic wedge bonding was introduced in the early 1960s. Thermosonic wedge bonding was first performed in 1970. Throughout the years several features have remained common among wedge bonding equipment, such as wire feeds through the tool and wire clamp behind the tool. Today's wedge bonders are vastly different, although the wire still feeds through the tool.

[Beck, Donald J. & Perez, Alberto. "The Great Debate: Ball vs. Wedge". Palomar Technologies.]

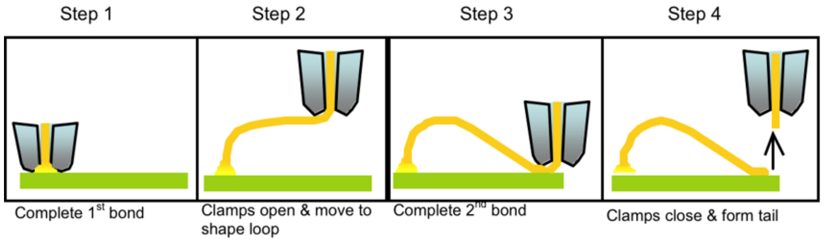
- Over the years, microelectronic wire bond process and packaging engineers have debated whether to use ball or wedge bond technologies. This has been especially true with RF designs and fine-pitch packaging.
- While ball bonding is faster and considered more robust, needs for low profile interconnects or fine pitch in key market segments requires wedge bonding.
- Another area where wedge bonding typically dominates is where a design requires a running stitch interconnect or die-to-die bonding. These demands have multiplied as advanced LED designs mature.

Brief History of Wire vs. Wedge Bonding

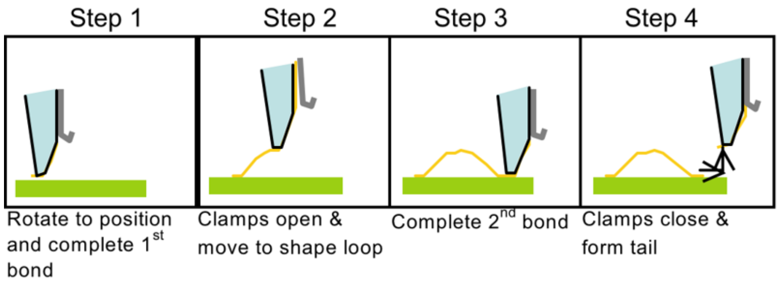
Automated wire bonders were introduced in the early 1980s. At this time, the majority of interconnects were made using aluminum wire. As the need for high reliability increased, gold wire became more common. As package densities increased, wire interconnect bond pitches decreased.

The initial solution to fine pitch was wedge bonding, because the wedge tool design allows wires to be bonded in close proximity (side-to-side).

Simplified representation of a typical wedge interconnect with 90° clamp feed



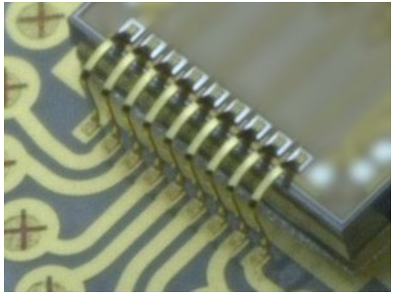
Simplified representation of a typical ball/crescent interconnect



Forward vs. Reverse Wedge Bonding

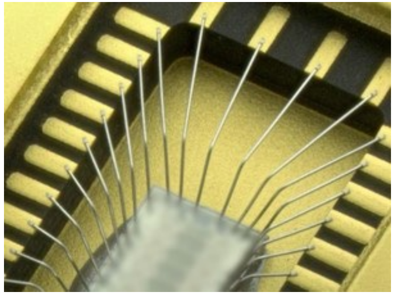
There are two basic types of wedge looping processes: **forward** and **reverse**. Wedge bonding can be a great solution for performing low profile or fine pitch interconnects and is also well suited for running stitch interconnects—also known as die-to-die bonding and chain bonding—reverse bonding, and ribbon bonding.

Forward Loops



A **forward looping process** places a wire bond on the die first, then places a stitch bond on the substrate. Forward bonding is less susceptible to edge shorts between the wire and die due to the natural upward angle at Bond one. By descending the wedge onto the IC bond pad, the wire is then pinned against the pad surface and an ultrasonic (U/S) or thermosonic (T/S) energy bond is created.

Reverse Loops



A **reverse bonding process**, however, begins on the substrate pad. After the connection is formed, a bond is placed on the die.

Designs that require interconnecting from die to die or from a substrate to a die benefit from the use of a wedge bonder.

Forward vs. Reverse Wedge Bonding

- Forward bonding is preferred, where the first bond is made to the die and the second is made to the substrate. As the first bond experiences less stress.
- Ball bonding and wedge bonding are the two wire bonding techniques that are used in thermocompression (T/C), thermosonic (T/S) and ultrasonic (U/S) bonding processes.
- Approximately 93% of all semiconductor packages are manufactured using ball bonding method, while wedge bonding is used to produce about 5% of all assembled packages.

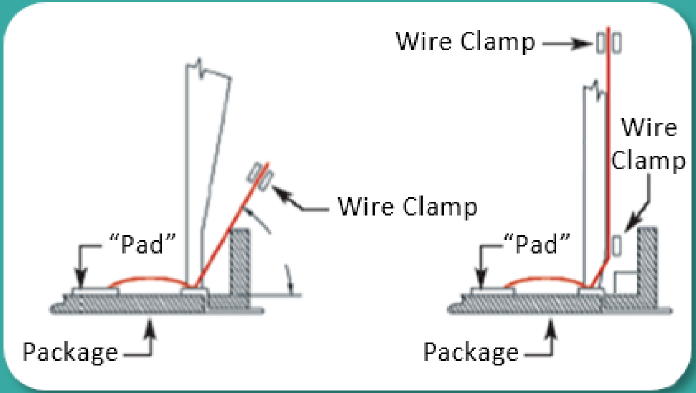
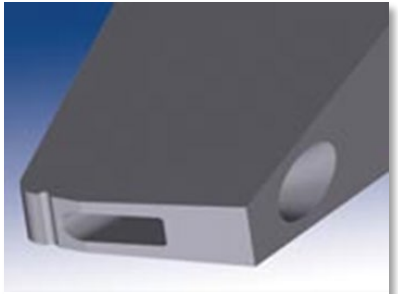


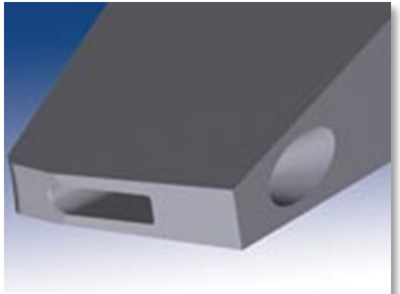
Image courtesy of: http://www.vps.nu/img/image/Docs/safe%20light.pdf

Basics of Ultrasonic Wedge Bonding

Historically, an angle degree change from the 45-60° to 90° required an expensive bond head change. The 9000 Wedge Bonder supports a simplified and cost-effective approach with a clamp change. This ensures greatest flexibility and scalability while keeping production costs low.



Example wedge tool for Au wire



Example wedge tool for Al wire

- Typical ultrasonic bonding processes begin by feeding the wire at the desired angle using a 45-60° wire clamp. The wire is thread from the horizontal bonding surface through a small canal on the wedge tool.
- When special clearance is necessary, the wire will be fed at 90° along the shank for maximum clearance.

Image credits: http://www.smallprecisiontools.com/products-and-solutions/chip-bonding-tools/wedge-bonding-tools/technical-overview/bonding-wedge-tools/

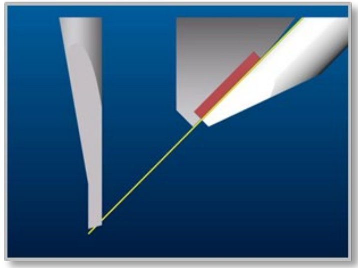
45-60° vs. 90° Deep Access

Wedge Angle Feed

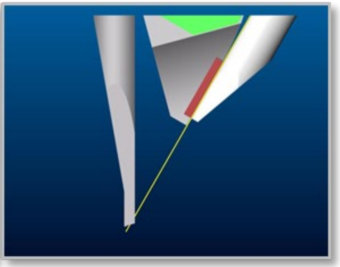
With evolving restrictions on wire diameter and wedge shape, many tooling manufacturers offer special tools to make precision shaped, gold wedge bonds for high frequency applications.

45-60°

45° Feed



60° Feed

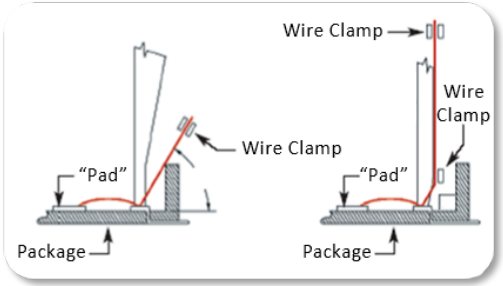


- Wider application usage
- Ability to bond quickly

90° Deep Access

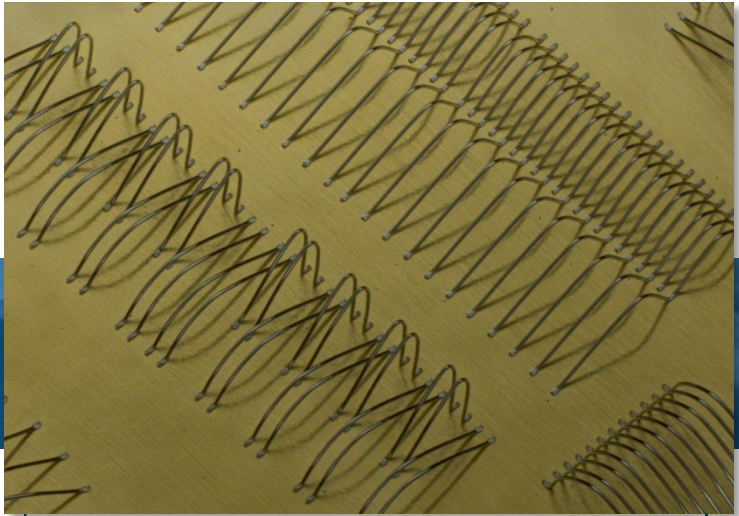
60° Angle Feed

90° Angle Feed

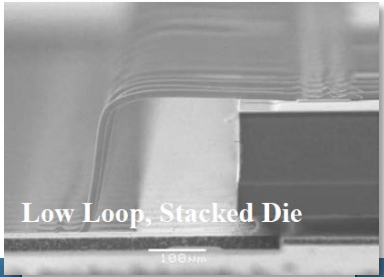


- Required for high package walls and where bonding to the edge of the die is necessary
- Possible decrease in bond speed in order to maintain best precision and reliability

Application Examples



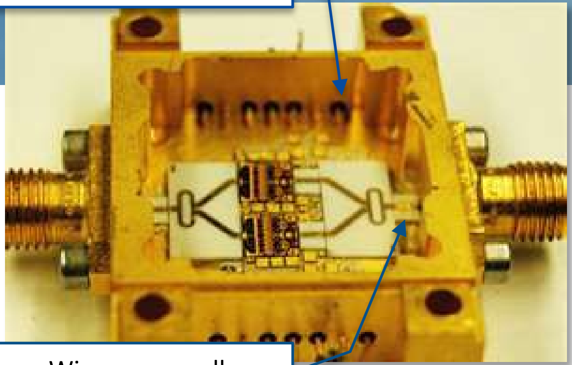
45-60° Angle Feeds



Package Clearance
Loop Height

90° Angle Feeds

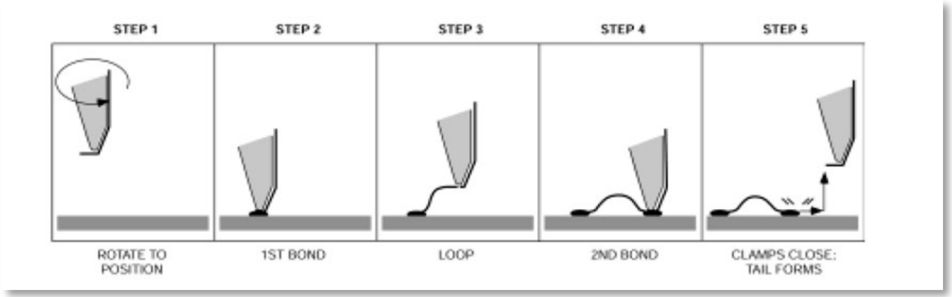
Wires near wall

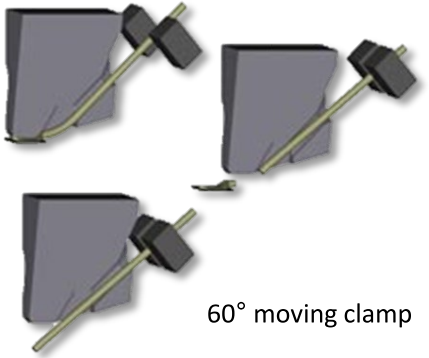


Wires near wall

Tail Formation

After the wedge rises and executes a desired loop shape, the wedge descends, making the second bond. During the loop formation, the movement of the axis of the bonding wedge feed hole must be aligned with the center line of the first bond, so that the wire can be fed freely through the hole in the wedge. There are several methods to end the wire after the second bond: clamp tear and table tear.





60° moving clamp

Clamp Tear

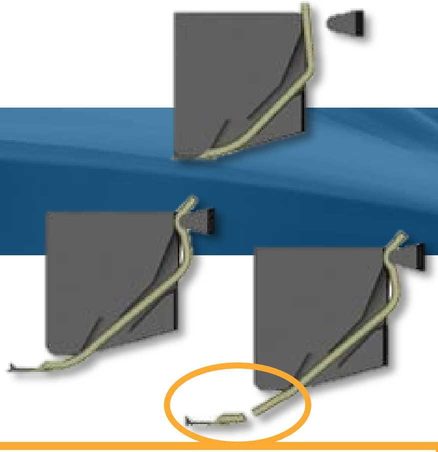
For small wires (<.003”/76µm), the clamp can be used to break the wire while machine bonding force is maintained on the second bond. The clamp tear process may offer a slightly higher throughput than the table tear process due to the force maintained on the second bond during the clamp tear motion, but is much more complicated program and may render a more expensive process. Larger wires can require a knife to assist in the wire tear.

Image credit: http://www.smallprecisiontools.com/products-and-solutions/chip-bonding-tools/wedge-bonding-tools/technical-overview/basic-ultrasonic-wedge-bonding-process/?oid=713&lang=en

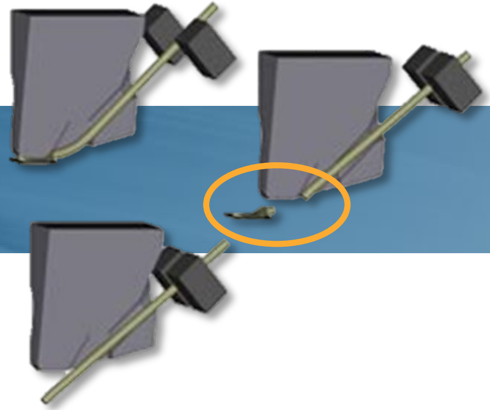
Tail Formation

Table Tear
If the clamp remains fixed relative to the wire direction and the bonding tool raises off the second bond, this process will tear the wire (table tear). The table tear process has a higher wire feed angle capability due to the back side of tool is as part of the clamp and has the potential to provide slightly more clearance from package obstructions such as a bond shelf or pin grid.

For large bonding wires (>.003"/76µm), the most common method is using a cutter blade. Once the wire is terminated, the wedge ascends. The clamped wire is fed under it to begin bonding the next wire—this process will repeat until the wire bond program is complete.



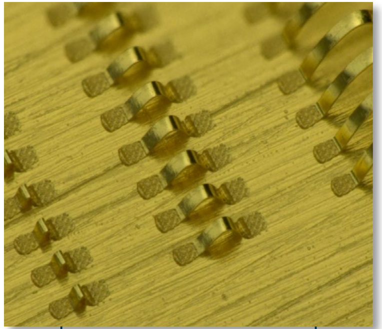
90° fixed clamp with table tear

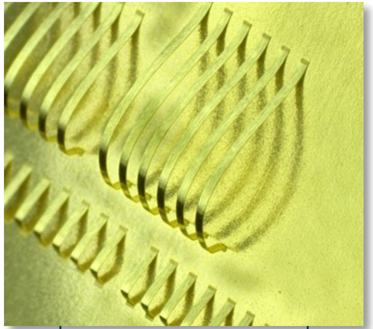


60° moving clamp

Image credit: http://www.smallprecisiontools.com/products-and-solutions/chip-bonding-tools/wedge-bonding-tools/technical-overview/basic-ultrasonic-wedge-bonding-process/?oid=713&lang=en

Ribbon Bonding

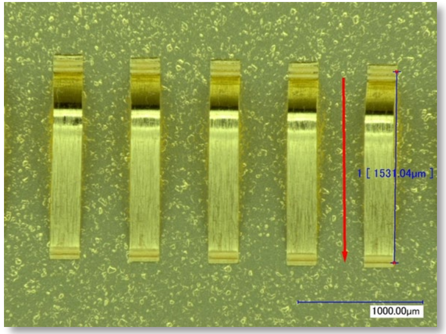

0.5x3mil Au on Au

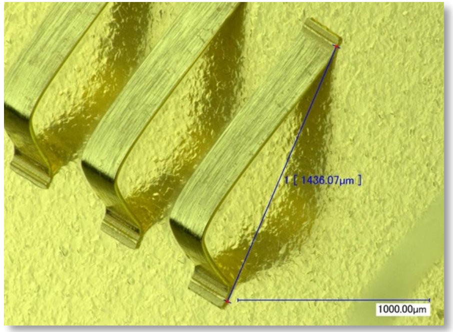

1x10mil Au on Au

Ribbon wire bonding improves signal performance, can carry higher current and is more delicate to fragile GaAs bonding pads. In addition, it generates stronger wire interconnects that last longer.

Until recently, ribbon interconnects were much larger and had to be soldered or welded into a circuit. Today, fully automatic fine wire ribbon bonders are available to assist circuit and packaging engineers with solutions to their formidable tasks.

Ribbon Bonding

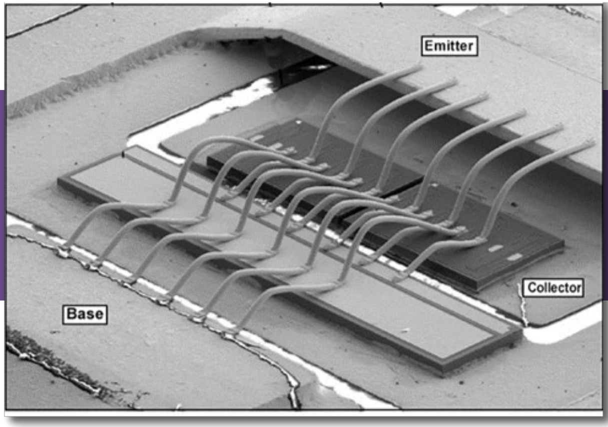




Until first-level interconnects are forced into alternate packaging technologies, ribbon wire will bridge the gap. It is rare indeed that a required technology actually improves a process. For the foreseeable future, ribbon wire will remain the dominant high frequency package interconnect of choice. Automated ribbon wire bonding is a true win-win solution.

Chain Bonding

RFSOE power transistors are traditionally wire bonded using gold wedge bonders to create strings of loops with each loop in the chain having specific length and height requirements.



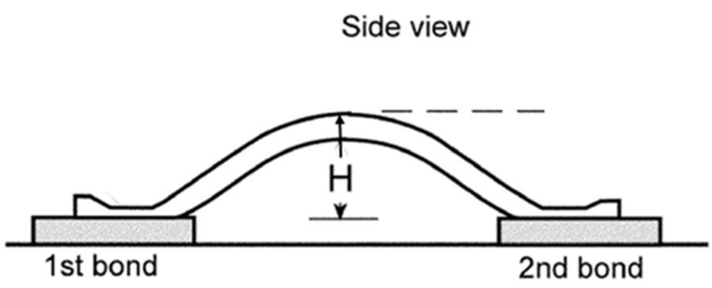
Fine Wire vs. Heavy Wire

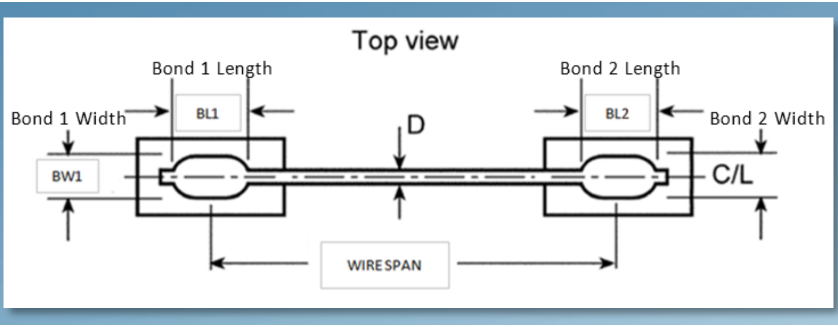
Today's industry standard classifies <2mil as fine wire and >3mil as heavy wire.

Fine Wire Applications	Heavy Wire Applications
• RF-SOE	• Hybrid automotive devices
• Disk Drives	• Automotive power components
• Large Complex Hybrids	• Automotive engine control modules
• RF and Microwave Devices	*partial list
• COB	
• Compact Hybrids	
• Fine Pitch Devices	
• High Frequency Passive and Active Components	
• MCM Power Connections	
• Fine Pitch Devices	
• Running Stitch Interconnects (die-to-die)	
• Ribbon Bonding	
• Low Profile Wire Bonds	

Anatomy of a Good Wedge Bond

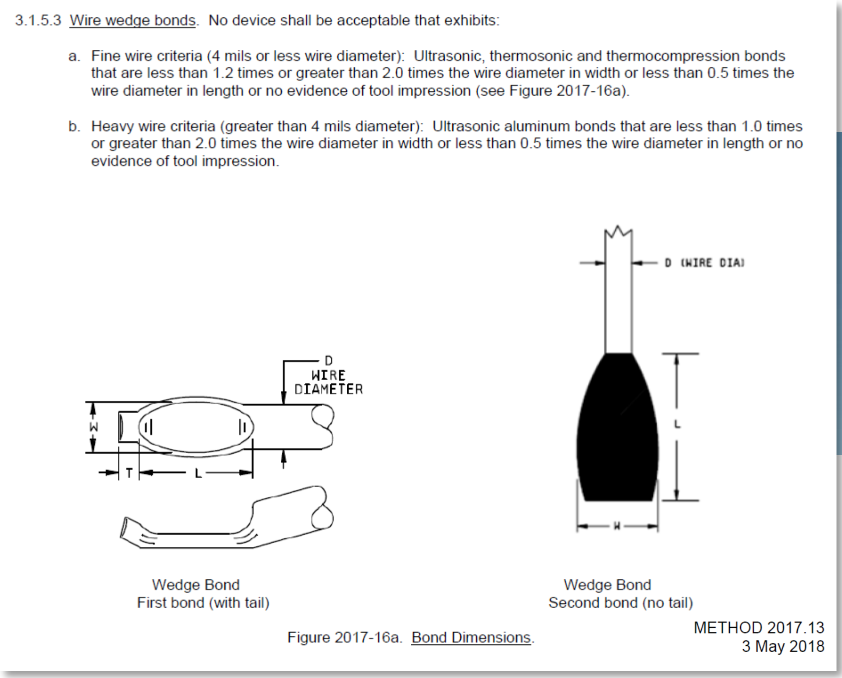
Measures – MilStd 883





Anatomy of a Good Wedge Bond

Measures – MilStd 883



3.1.5.3 Wire wedge bonds. No device shall be acceptable that exhibits:

a. Fine wire criteria (4 mils or less wire diameter): Ultrasonic, thermosonic and thermocompression bonds that are less than 1.2 times or greater than 2.0 times the wire diameter in width or less than 0.5 times the wire diameter in length or no evidence of tool impression (see Figure 2017-16a).

b. Heavy wire criteria (greater than 4 mils diameter): Ultrasonic aluminum bonds that are less than 1.0 times or greater than 2.0 times the wire diameter in width or less than 0.5 times the wire diameter in length or no evidence of tool impression.

Wedge Bond
First bond (with tail)

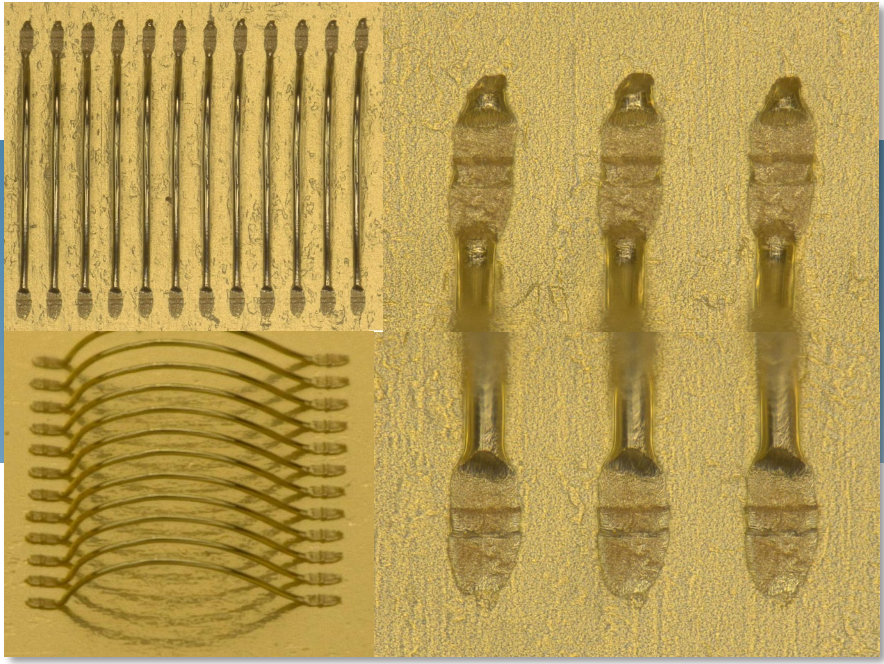
Wedge Bond
Second bond (no tail)

Figure 2017-16a. Bond Dimensions.

METHOD 2017.13
3 May 2018

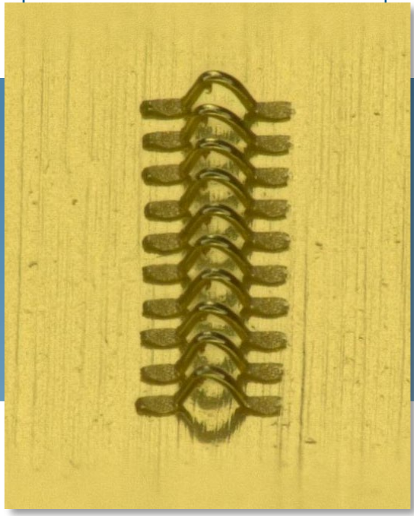
Anatomy of a Good Wedge Bond

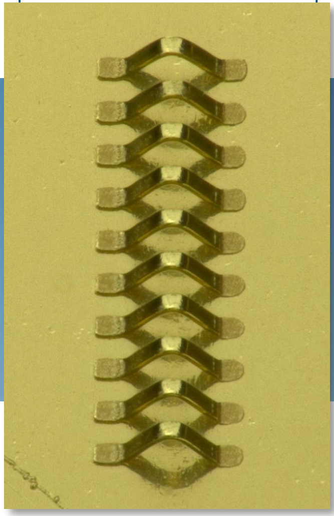
Measures – MilStd 883

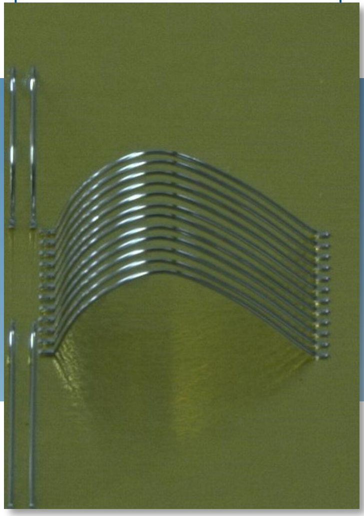


Anatomy of a Good Wedge Bond

Measures – MilStd 883

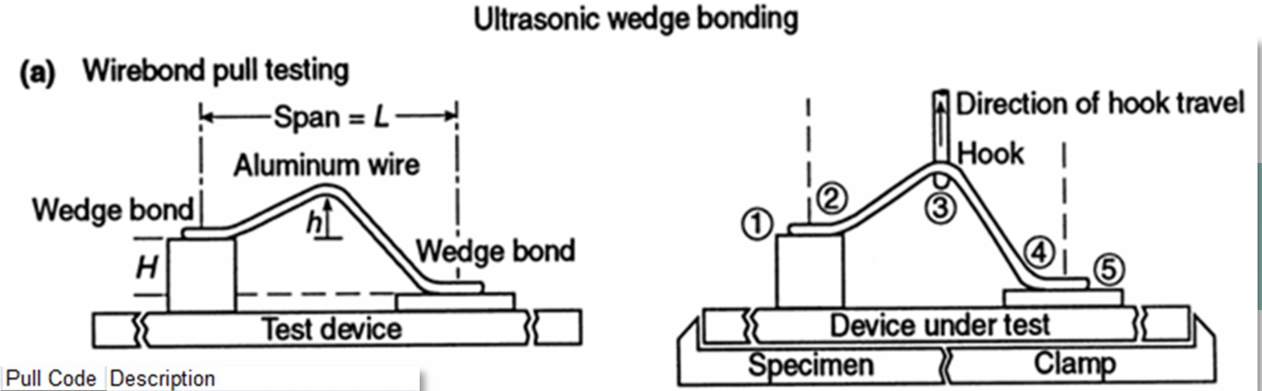

0.7 mil Au


0.5x3 mil Au Ribbon


2 mil Al wire

Wedge Bond Testing

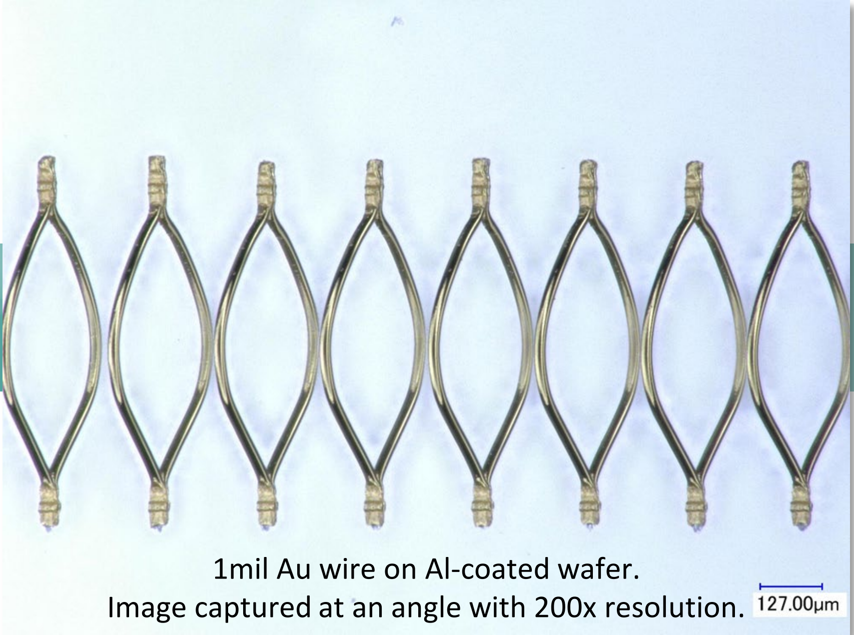
Measures – MilStd 883



Pull Code	Description
1	First bond lift
2	First bond break at transition
3	Mid-span break
4	Second bond break at transition
5	Second bond lift

Examples of High-Quality Wedge Bonds

Bonds created on the 9000 Wedge Bonder



1mil Au wire on Al-coated wafer.
Image captured at an angle with 200x resolution.

Detecting Poor Quality Wedge Bonds

Precision, reliability and consistency should all be reflected in automated wedge bonding.

Indicators of poor quality wedge bonds include:

- Inconsistent tails
- Inconsistent loop heights
- Inconsistent loop lengths
- Leaning loops
- Over bonding

9000 Wedge Bonder solutions

9000 Wedge Bonder Wire Sizes and Materials

Throughput	6 Wires per second 10 loops per second
Repeatability	1µm, 3σ
Wire Size (Au & Al)	17.5µm -75µm (0.7mil – 3 mil)
Ribbon Size (Au)	12.7µm x 50.8µm up to 25.4µm x 254µm (0.5mil x 2mil up to 1mil x 10 mil)

Download the
9000 Wedge Bonder data sheet

Summary

Wedge bonding is a technical process with a long history, tracing back to early developments in the 1950s. In recent years, microelectronic wire bond process and packaging engineers have debated whether to use ball or wedge bond technologies with applications such as RF designs and fine-pitch packaging. Low profile interconnects or fine pitch in key market segments requires wedge bonding.

New methods and control tools are available today to meet modern wedge bond needs.

There are two basic types of wedge looping processes: forward and reverse. Forward bonding is preferred, where the first bond is made to the die and the second is made to the substrate.

There are two main wire feed angle categories: 45-60° and 90° deep access.

Today's industry standard classifies <2mil (50.8µm) as fine wire and >3mil (75µm) as heavy wire.

There are several methods to end the wire after the second bond: clamp tear and table tear (better option).

Ribbon bonding improves signal performance; while chain bonding is traditionally used for RFSOE power transistors.

Precision, reliability and consistency should all be reflected in automated wedge bonding. There are MilStd 883 guidelines for measurements and testing to ensure quality wedge bonding.

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