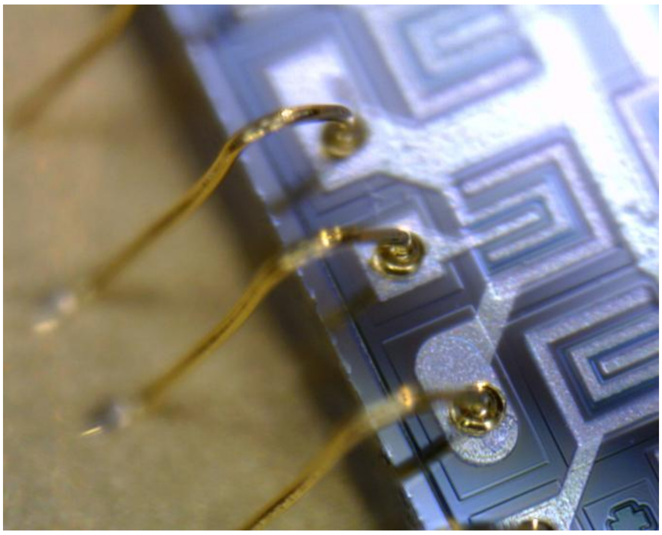
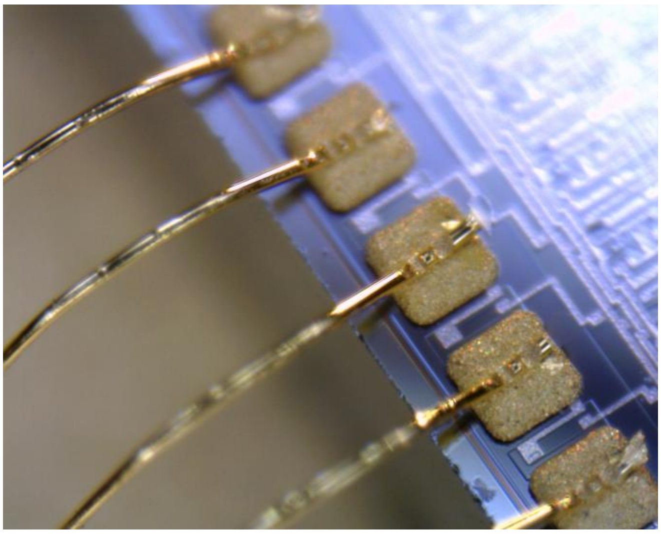
Wire Bonder

Wire Bonding Basics

Franz Hickmann

Version 4.0





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1. Introduction to Wire Bonding

Ultrasonic bonding development:

Ultrasonic bonding was discovered 1960 through a fortuitous experimental observation and has subsequently been developed into a highly controlled process. In recent years it has been used extensively for electrical interconnecting of semiconductor chips and packaging of wire which connects ultrasonic bonding to the outside world.

Today, ultrasonic bonding is a different process from what it was originally thought to be. The concept of interfacial rubbing is not valid. Ultrasonic energy, when applied to metal to be bonded, renders it temporarily soft and plastic. This causes the metal to flow under pressure. The acoustic energy frees the dislocation from their pinned positions which allows the metal to flow under the low compressive forces of the bond. Thus heat at the bond becomes a byproduct of the bonding process, and the heat becomes unnecessary to form the bond. The deformation of the wire will break up and sweep aside the contaminants in the weld area. This exposes extremely clean metallic surfaces which promotes the metallurgical bonds. It was also found that the bonding tool moves cyclically across the top of the wire. It does not grip the wire, and this causes the wire to slip back and forth across the bonding area. This is called a cold weld.

2. Wire Bonding is *Micro Welding* which does not melt metal.

Processes which melt metal	Gas Welding Arc Welding Resistance Welding Laser Welding E-Beam Welding Induction Welding
Process which does not melt metal	Solid State Welding (Cold Weld = Wire Bonding)

3. Bonder Types

Ball Bonder:	A machine that presents the wire vertically through a bonding tool, forms a ball on the end of the wire, applies bonding energy and sever s the wire after the terminating bond, and forms a ball for the next bond.
Wedge Bonder:	A machine that presents the wire at an angle under a bonding tool, applies bonding energy and severs the wire after the terminating bond, and repositions the loose end of the wire under the bond tool for the next bond.

4. Difference between Ball and Wedge-Bonding

	Advantage	Disadvantage
Ball-Bonding	• Easier to bond • Faster bonding	• Only Gold wire • Larger Pads necessary • Heat necessary
Wedge-Bonding	• For Gold and Al Wires • Small Pads possible • No heat by Al necessary	• More complicated • Slow bonding speed • Bonding only in one direction

5. Energy Methods

1. Thermosonic - Uses 4 variables for Gold and Aluminium wire

a.	Work piece Heat	100°C - 150°C
b.	Force	20-200 gm
c.	Ultrasonic Energy	60 K Hz / 1 – 5 Watt
d.	Time	20-200 ms

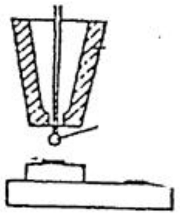
2. Ultrasonic - Uses 3 variables for Aluminium wire

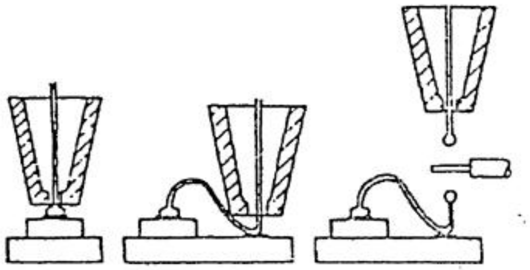
a.	Force	20-200 gm
b.	Ultrasonic Energy	60 K Hz / 1 – 5 Watt
c	Time	20-200 ms

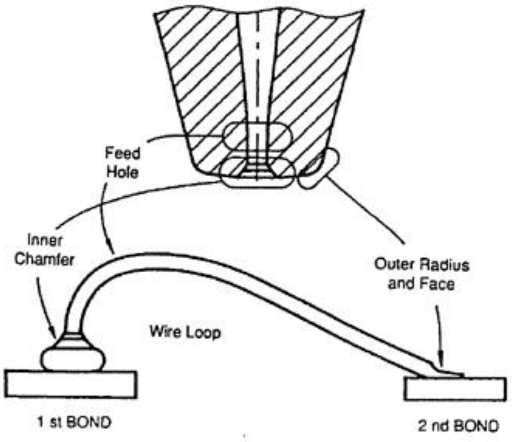
6. Energy Terms

Force:	Used to promote plastic flow (Deformation) and intimate coupling between the bonding tool, the wire, and the workpiece. Measured in grams.
Workpiece Heat:	In thermosonic bonding, eliminates surface contaminants and softens the metalization. In thermocompression bonding, brings the workpiece metalization to its plastic state.
Tool Heat:	Cleans and anneals the wire and prevents the tool from "heat sinking" on contact with the workpiece.
Ultrasonic Energy:	Displaces surface contaminants and insures metal-to-metal coupling, excites loose electrons (e++) in the outer valence levels to share with loose electrons (e++) in adjacent molecules thus causing a series of co-valent bonds and forming a bi-metallic at the coupling plane of the two metals (Solid State Diffusion).
Bond Duration:	Time lapsed from intimate touch down and bond completion.

7. Ball - Bonding







7.1 Ball-Bonder, Ball Formation

The bonding process begins with forming a ball by melting the end of the wire. Originally (and to a small extent, today), the wire was melted by a hydrogen flame.

An electric flame-off (EFO) was developed to melt the ball. The easiest method was to charge the electrode positive and the wire negative. Most bonders today are positive EFO. This polarity melts the wire with the least amount of energy. A relatively simple power supply can be used to create the spark and to vary the amount of melt. However, there are sophisticated positive EFO power supplies availble that can control small ball sizes. Figure 5 is a diagram of a ball-forming EFO.

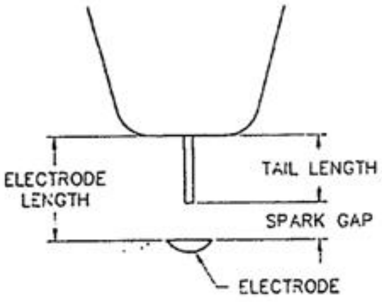


Figure 5 — Diagram of EFO and Capillary.

There are several problems with the positive EFO. When trying to form a smaller ball size, it can be difficult to maintain consistency when using a simple power supply. The capillary tip cone area becomes coated with carbon and metal, creating a black coating. Wear to the tip of the capillary is directly influenced by the power setting and ball position.

During the ball formation, using positive EFO, the wire and ball are surrounded by plasma (ionized air). This shroud of plasma completely encircles the ball and is about .002 inches thick. It extends up from the ball about .004 inches as shown in Figure 6. The plasma shroud can be viewed from the side using a microscope of 30× or more during automatic bonding.

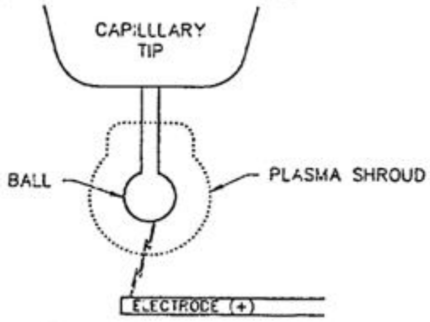


Figure 6 — Plasma shroud surrounding the ball using positive EFO.

If the ball is formed away from the capillary tip, (i.e., over .005 inches), there is little damage to the tip. However, a common practice is to allow the ball to melt against the face of the tip as shown in Figure 7. The plasma now contacts the tip and etches the inside chamfer area.

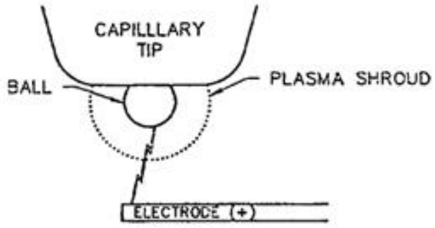


Figure 7 — Plasma shroud touching the face causing plasma etching.

When making small balls, it is common to adjust the tail length short and form the ball against the tip, causing rapid damage.

A more recent innovation is the negative EFO where the electrode is negative and the wire is positive. Forming the ball with this polarity is more difficult than with positive EFO. The power supply is more sophisticated, having timing and current-limiting circuits.

Forming a small ball with negative EFO is very consistent without having to form it against the capillary tip. However, an added feature is that the plasma shroud covers only the bottom half of the ball as shown in Figure 8.

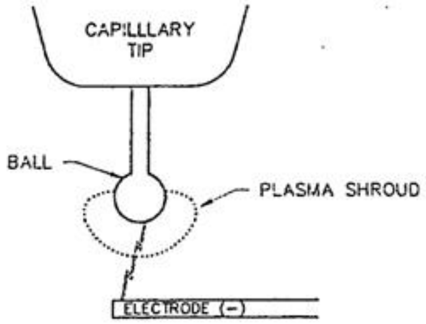


Figure 8 — Plasma shroud on bottom side of the ball using a negative EFO.

The fact that the plasma only covers the bottom half of the ball still allows the ball to be formed against the tip without causing any damage to the I.C. area. Therefore, the advantages of negative EFO are consistent small ball size and longer capillary life. The disadvantage is the negative EFO shortens electrode life.

7.2 Ball-Bonder, Loop Sequence

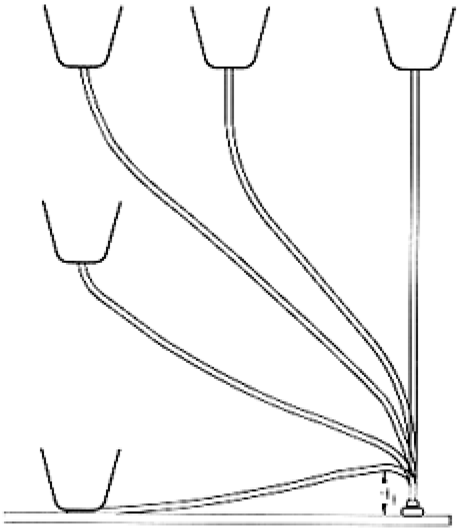


Figure 1 — The basic motion for making wire bonds is illustrated above. After the ball is formed on the wire the tool lowers to make the ball bond. The tool raises vertically to a high "loop" position. The work-stage or tool head moves horizontally. When the second bond position is reached the tool lowers to make the stitch bond. Some wire feeds back into the tool during the downward motion. When the second bond is completed the resultant loop can be low as H_1 shows. This simple rectangular tool motion can be used for relatively short loop lengths.

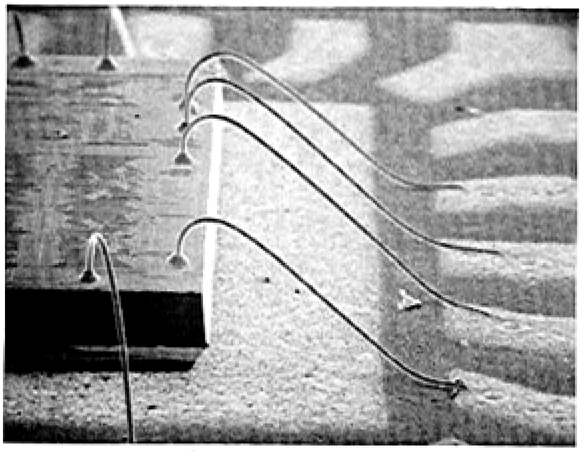


Figure 2 — The above loops were made with the simple rectangular motion. The loops are generally low in profile. The low profile is acceptable for relatively short loop lengths and for IC devices that have the bond pads close to the edge.

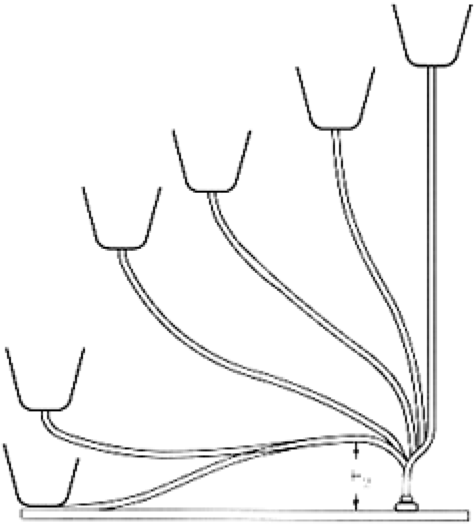


Figure 3 — The looping motion for high speed bonders is referred to as reverse-motion as shown above. The tool raises about .010 in. after the ball bond and the relative tool motion is made in the opposite direction of the loop. This motion is for a short distance to make a set in the wire. The tool moves vertically to the "loop" position similar to the rectangular motion. The relative tool motion is in an arc down to the second bond to complete the loop. The high loop H_2 allows bonding to pads on a device that are inside from the edge. The higher loop allows longer loops with less sagging.

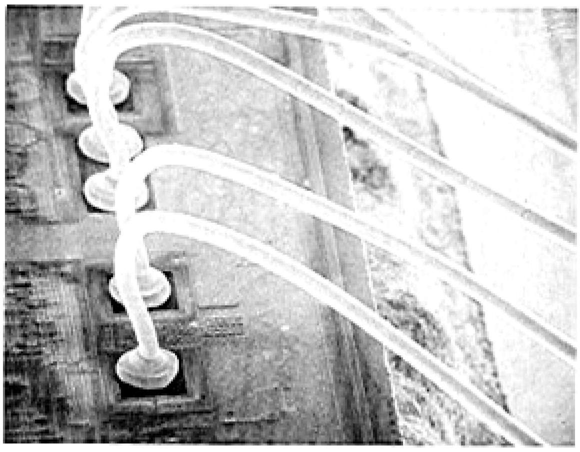


Figure 4 — The above loops were made with the reverse-motion. The loops are generally higher in profile than those made with rectangular motion. This high loop is desirable for bonding pads that are in-set from the edge of the device.

7.3 Ball-Bonder, Ball / Wedge / Capillary

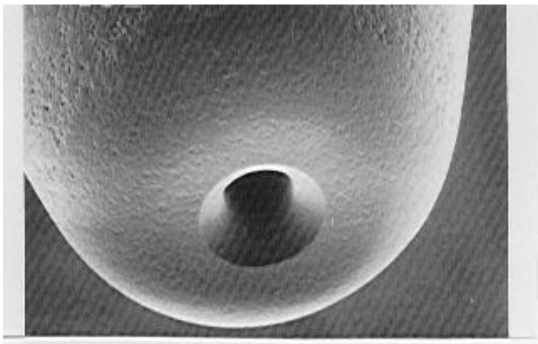


Abb. 2. Bond-Kapillare

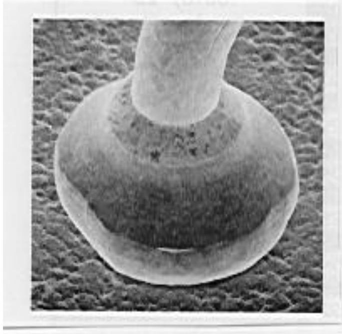


Abb.3 Ball-Bond

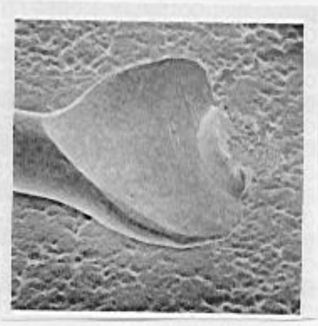
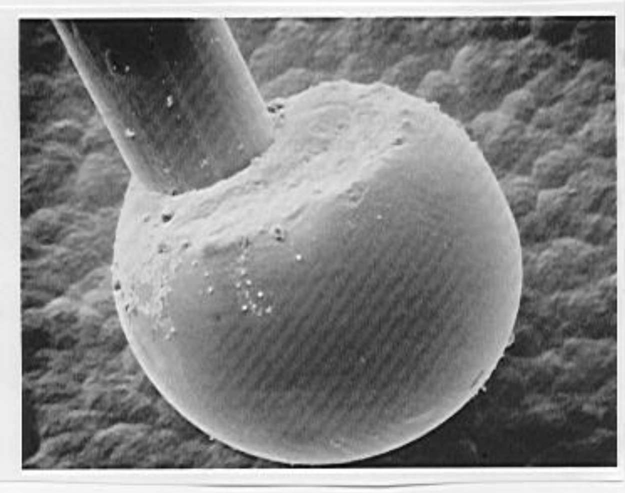
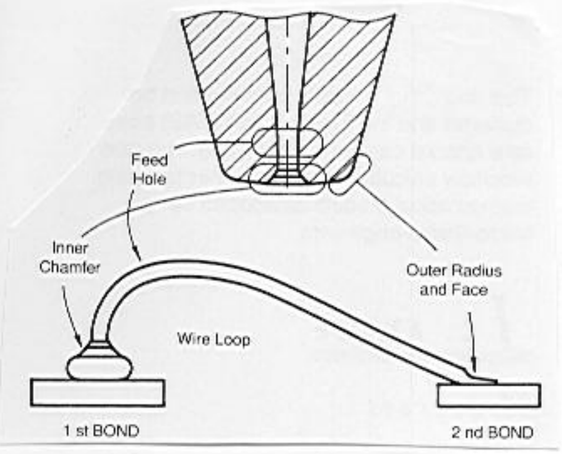
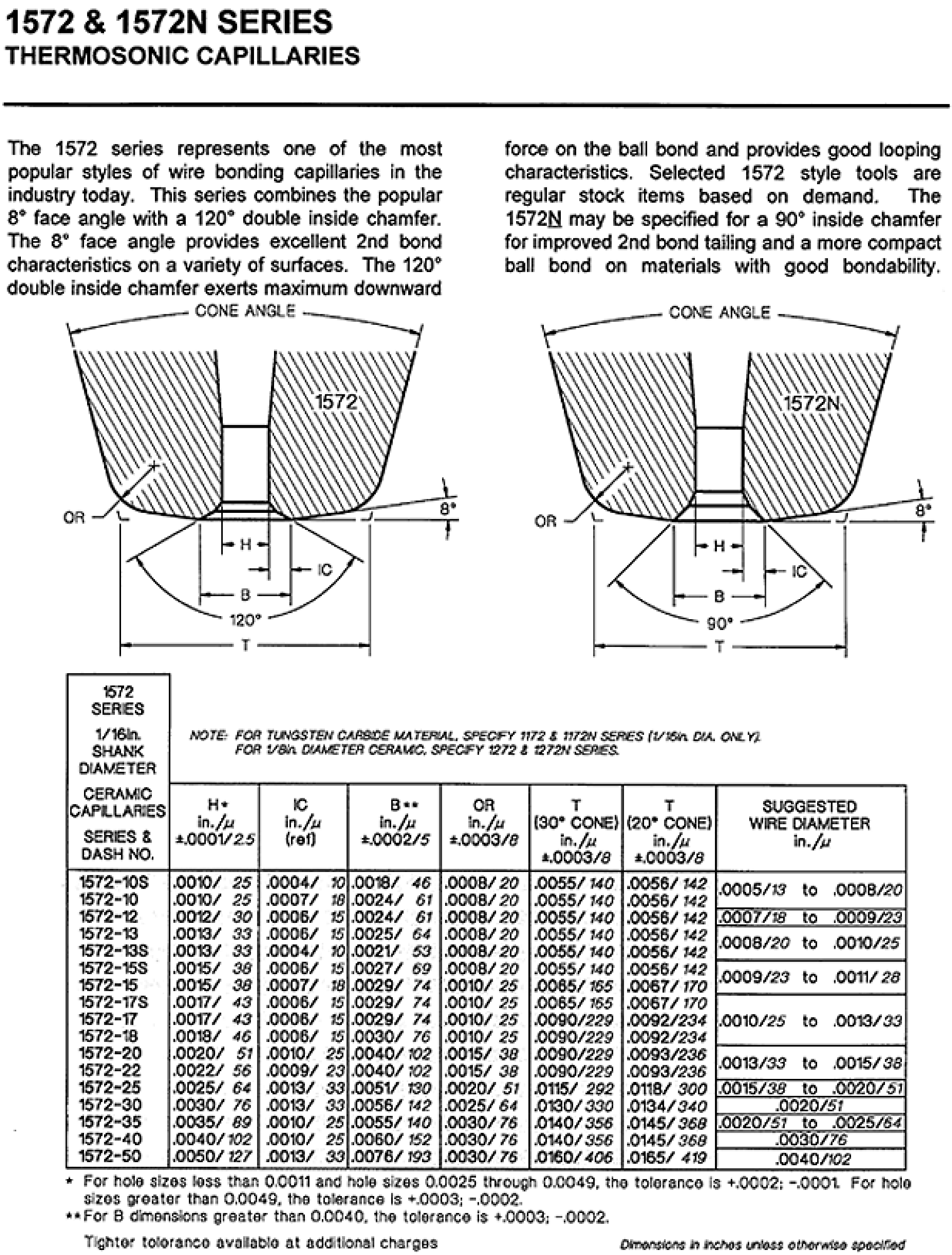


Abb.4 Wedge Bond





7.4 Ball-Bonder, Capillaries



1572 & 1572N SERIES
THERMOSONIC CAPILLARIES

The 1572 series represents one of the most popular styles of wire bonding capillaries in the industry today. This series combines the popular 8° face angle with a 120° double inside chamfer. The 8° face angle provides excellent 2nd bond characteristics on a variety of surfaces. The 120° double inside chamfer exerts maximum downward force on the ball bond and provides good looping characteristics. Selected 1572 style tools are regular stock items based on demand. The 1572N may be specified for a 90° inside chamfer for improved 2nd bond tailing and a more compact ball bond on materials with good bondability.

NOTE: FOR TUNGSTEN CARBIDE MATERIAL, SPECIFY 1172 & 1172N SERIES (1/16in. DIA. ONLY).
FOR 1/8in. DIAMETER CERAMIC, SPECIFY 1272 & 1272N SERIES.

1572 SERIES 1/16in. SHANK DIAMETER CERAMIC CAPILLARIES SERIES & DASH NO.	H* in./µ ±.0001/2.5	IC in./µ (ref)	B** in./µ ±.0002/5	OR in./µ ±.0003/8	T (30° CONE) in./µ ±.0003/8	T (20° CONE) in./µ ±.0003/8	SUGGESTED WIRE DIAMETER in./µ
1572-10S	.0010/ 25	.0004/ 10	.0018/ 46	.0008/ 20	.0055/ 140	.0056/ 142	.0005/13 to .0008/20
1572-10	.0010/ 25	.0007/ 18	.0024/ 61	.0008/ 20	.0055/ 140	.0056/ 142	
1572-12	.0012/ 30	.0006/ 15	.0024/ 61	.0008/ 20	.0055/ 140	.0056/ 142	.0007/18 to .0009/23
1572-13	.0013/ 33	.0006/ 15	.0025/ 64	.0008/ 20	.0055/ 140	.0056/ 142	.0008/20 to .0010/25
1572-13S	.0013/ 33	.0004/ 10	.0021/ 53	.0008/ 20	.0055/ 140	.0056/ 142	
1572-15S	.0015/ 38	.0006/ 15	.0027/ 69	.0008/ 20	.0055/ 140	.0056/ 142	.0009/23 to .0011/ 28
1572-15	.0015/ 38	.0007/ 18	.0029/ 74	.0010/ 25	.0065/ 165	.0067/ 170	
1572-17S	.0017/ 43	.0006/ 15	.0029/ 74	.0010/ 25	.0065/ 165	.0067/ 170	.0010/25 to .0013/33
1572-17	.0017/ 43	.0006/ 15	.0029/ 74	.0010/ 25	.0090/229	.0092/234	
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1572-22	.0022/ 56	.0009/ 23	.0040/ 102	.0015/ 38	.0090/229	.0093/236	
1572-25	.0025/ 64	.0013/ 33	.0051/ 130	.0020/ 51	.0115/ 292	.0118/ 300	.0015/38 to .0020/ 51
1572-30	.0030/ 76	.0013/ 33	.0056/ 142	.0025/ 64	.0130/ 330	.0134/ 340	.0020/51
1572-35	.0035/ 89	.0010/ 25	.0055/ 140	.0030/ 76	.0140/ 356	.0145/ 368	.0020/51 to .0025/64
1572-40	.0040/ 102	.0010/ 25	.0060/ 152	.0030/ 76	.0140/ 356	.0145/ 368	.0030/76
1572-50	.0050/ 127	.0013/ 33	.0076/ 193	.0030/ 76	.0160/ 406	.0165/ 419	.0040/102

* For hole sizes less than 0.0011 and hole sizes 0.0025 through 0.0049, the tolerance is +.0002; −.0001. For hole sizes greater than 0.0049, the tolerance is +.0003; −.0002.

** For B dimensions greater than 0.0040, the tolerance is +.0003; −.0002.

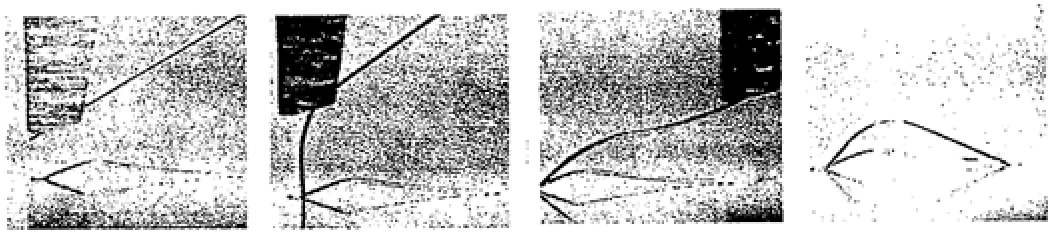
Tighter tolerance available at additional charges

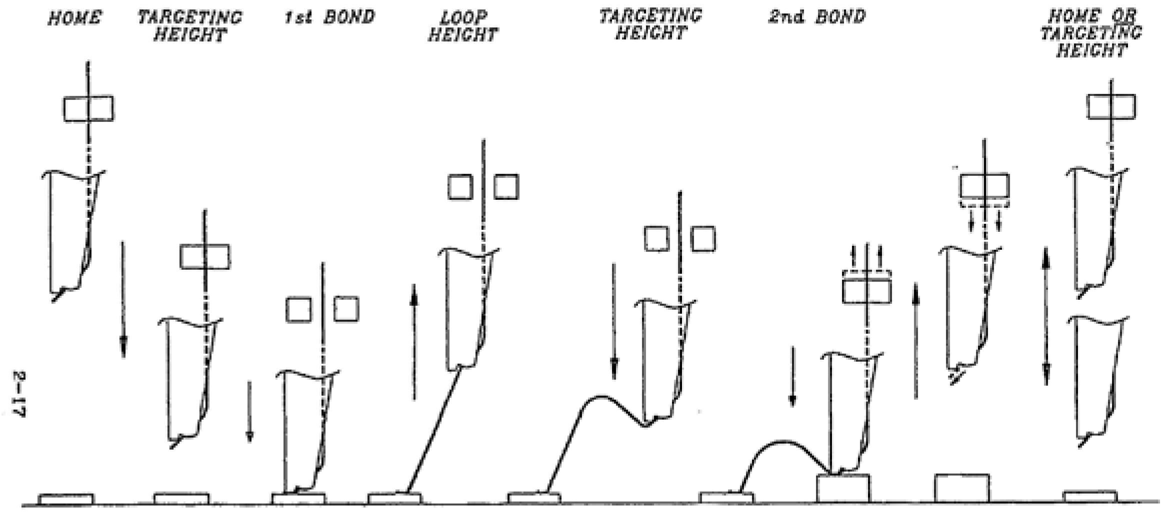
Dimensions in inches unless otherwise specified

8. Wedge-Bonding

Wedge bonding is a solid state process. The primary bonding parameters in wedge bonding are ultrasonic power, force, and time. When bonding gold wire, the fourth parameter of heat is added. Wedge bonding joins two pieces of metal using a process of diffusion. The bonding wire is mechanically bonded to the die pad or package metalization by rubbing the surfaces of the wire and metalizations together. This rubbing occurs by vibrating a clamped wedge at ultrasonic frequency while the wire is held under the bond foot of the wedge. Commonly called scrubbing, this rubbing disturbs any surface oxide film, exposes clean metallic surfaces and forms a metallurgical weld. This metallurgical weld is not degraded significantly by heat.

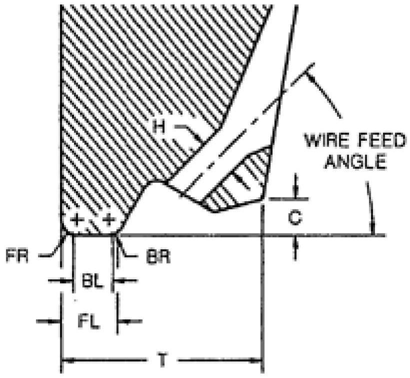
Microwave diodes, Transistors and GaAs devices generally have gold as their surface layer and have small bonding pads. Some of these bonding pads measure less than 0.002in./51µ inches across and less than 0.004in./102µ on center. The advantage of wedge bonding over ball bonding is the ability to form bonds on such narrow closely spaced bond pads. Typical wire diameters for microwave applications range from 0.001in./25µ to 0.0005in./13µ. Most microwave devices are wedge bonded with gold wire.



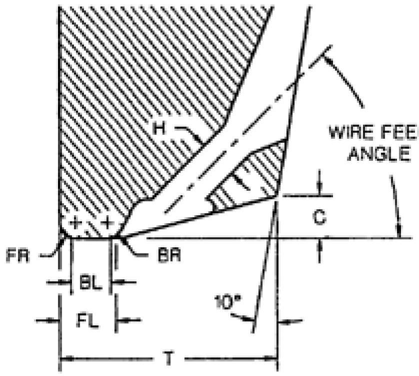


8.1 Wedge–Bonding, Wedge Design

The design of wedges over the last ten years has changed very little with the exception of the introduction of deep access wedge bonding. Most bonder manufacturers now offer a wedge bonder that enables the wire to travel through the center or down the back of the wedge vertically. The tip configurations on these deep access wedges are generally the same as those offered for conventional bonding. The two tip configurations of wedges Gaiser offers are the V-notch and Maxiguide style.

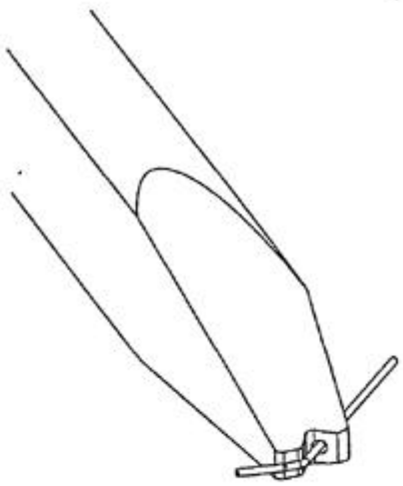


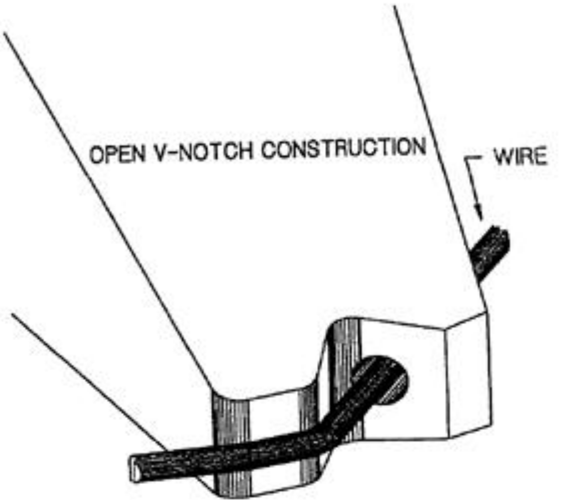
Cross-sectional view of a V-notch wedge identifying the standard dimensions.

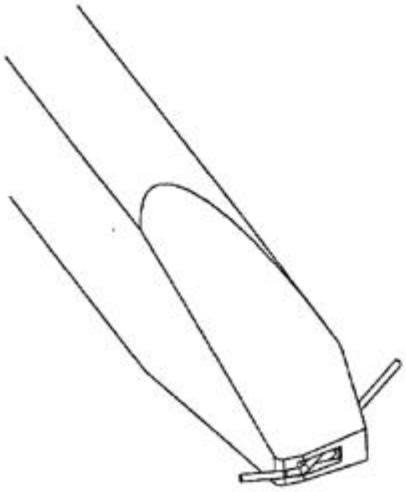


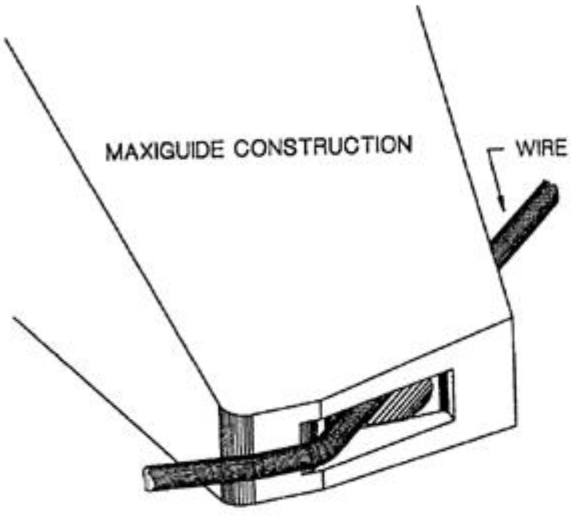
Cross-sectional view of a Maxiguide wedge identifying the standard dimensions.

8.2 Wedge-Bonding, V-Notch & Maxiguide Wedge





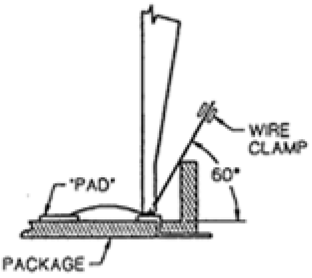




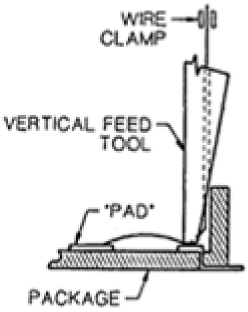
8.3 Wedge-Bonding, 90° Wedge Tool

There are several advantages to wedge bonding. One advantage is the ability of wedges to accommodate the increasing demand for bond-pitch applications below 0.004in./102µ. Another advantage is that the wire has minimal bond deformation width so the wire can be placed on a very narrow pad. In many cases, these two are related. Likely the greatest advantage is that wedge bonding allows the bonding of aluminum wire.

Another advantage of wedge bonding over ball bonding is the ability to bond down into deep cavities and packages. Standard wedge tool lengths are available up to 1.078in./27mm as compared to 0.750in./19mm tool lengths for ceramic capillaries. The problem with conventional wedge bonding down into these deep geometry's has been that, even with a 60° wire feed angle, the wire can interfere with the package wall or another device. 90° Deep access wedge bonding differs from conventional wedge bonding by feeding the wire down through the center of the wedge. Deep access wedge bonding allows accessibility similar to a capillary.



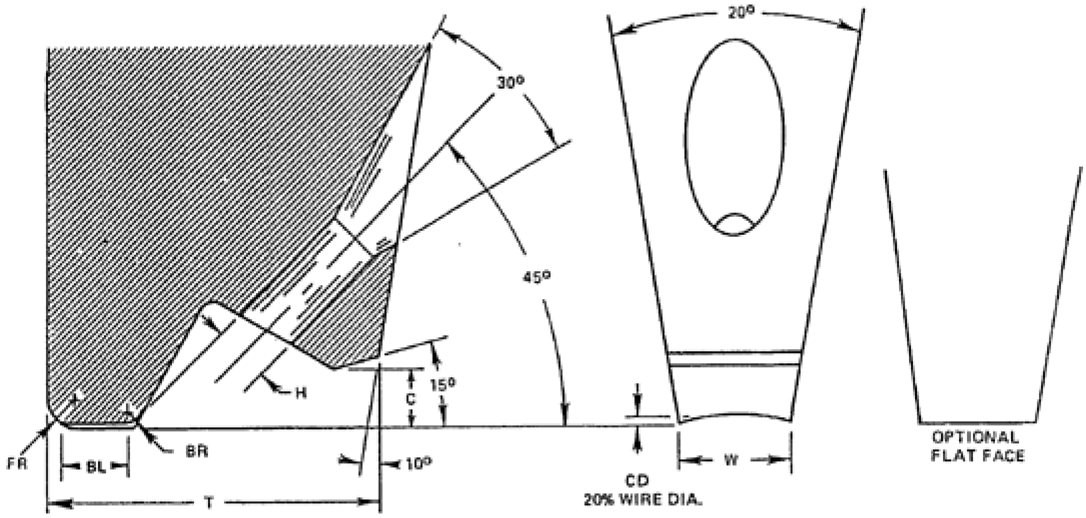
Conventional wedge bonding has limited accessibility due to the wire and clamp being located behind the wedge .

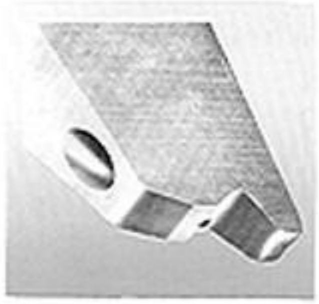


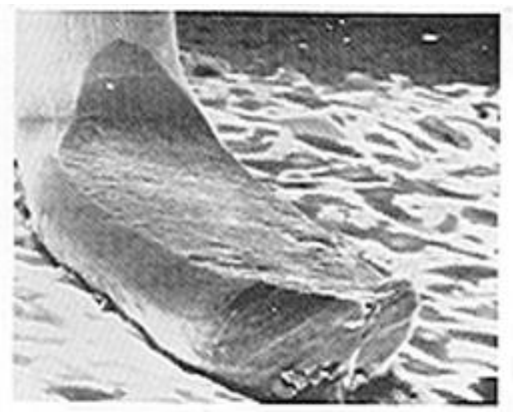
90° Deep access wedge bonding utilizes a through-the-wedge design. The wire feeds down through the center of the wedge, exits the wedge and then re-enters the wedge at the tip. This design allows for accessibility similar to a capillary.

A principle disadvantage of wedge bonding is the wire is fed at a 30°, 45° or 60° horizontal angle rather than perpendicular as in ball bonding. Also, wedge bonding is unidirectional. This is slower than ball bonding which is multidirectional. Wedge bonding requires the circuit workpiece or the bonding head to rotate to allow for the wire to bond in the appropriate direction.

8.4 Wedge-Bonding, Wedge Tool

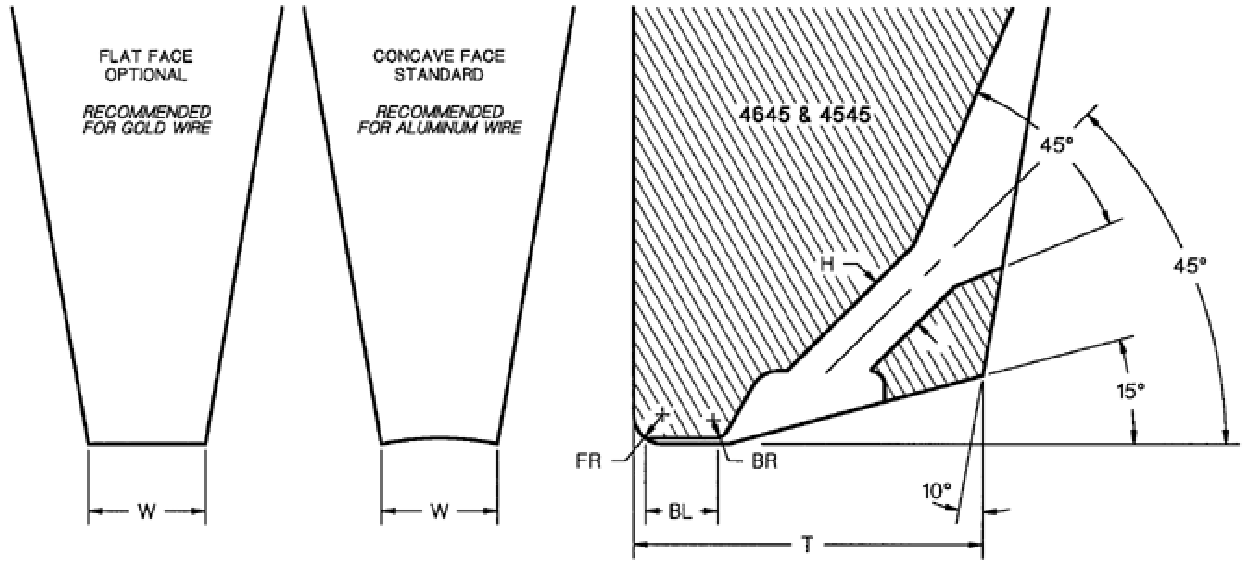


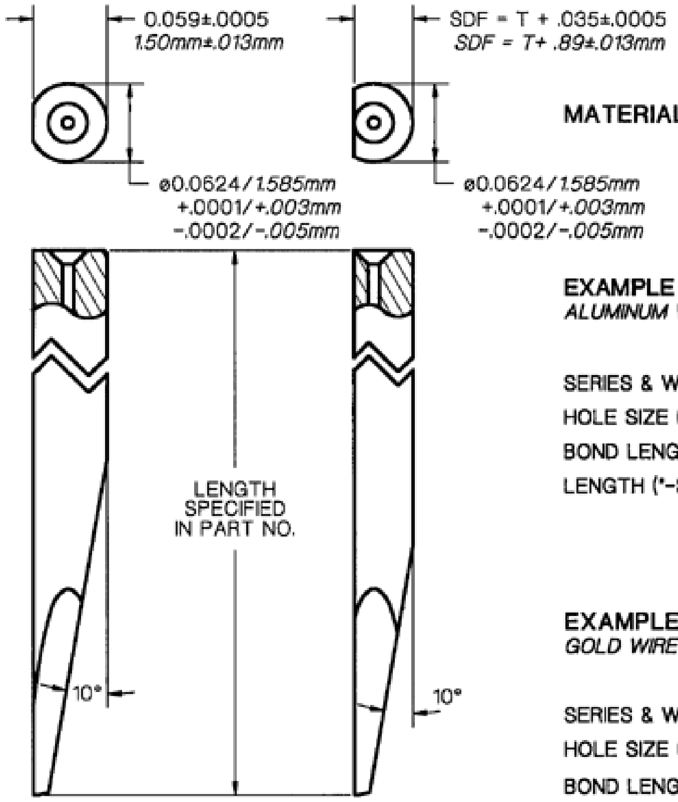




8.5 Wedge-Bonding, Deep Access V-Notch Wedges

4645 & 4545 SERIES
DEEP ACCESS MAXIGUIDE WEDGES





4645 STANDARD SHANK DESIGN

4545 CLOSE GUIDE SHANK DESIGN

MATERIAL: TUNGSTEN CARBIDE STANDARD
TITANIUM CARBIDE TIP OPTIONAL (SPECIFIY "-TIC" IN PART NO.)
CERMET TIP OPTIONAL (SPECIFIY "-CER" IN PART NO.)

EXAMPLE PART NUMBER:
ALUMINUM WIRE

4545-2025-S

SERIES & WIRE FEED ANGLE
HOLE SIZE ("20"=0.0020In.)
BOND LENGTH ("25"=0.0025In.)
LENGTH ("-S"=0.437In.)

EXAMPLE PART NUMBER:
GOLD WIRE

4545-2025-3/4-F

SERIES & WIRE FEED ANGLE
HOLE SIZE ("20"=0.0020In.)
BOND LENGTH ("25"=0.0025In.)
LENGTH ("3/4"=0.750In.)
FLAT FACE ("-F")

8.6 Wedge Tool Specification

Recommend Wedge Tool for TPT Wire Bonder

WIRE SIZE	PART NUMBER	GAISER TOOLS
17µm /.7 mil	4445-1515-3/4-F	
25µm /1.0 mil	4445-1520-3/4-CG	
30µm / 1.2 mil	4445-2525-3/4-CG	

Example: 44 45 - 2 0 1 5 3/4 - F

Style

Flat Foot

45° feed Angle

Hole dia. in tip

Bond length (foot)

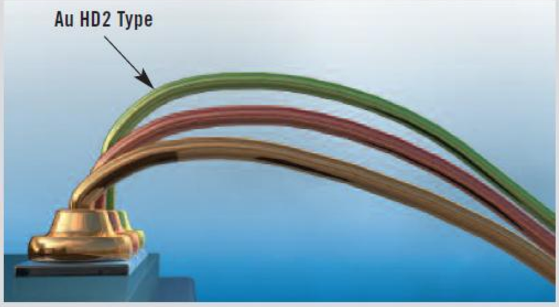
Length

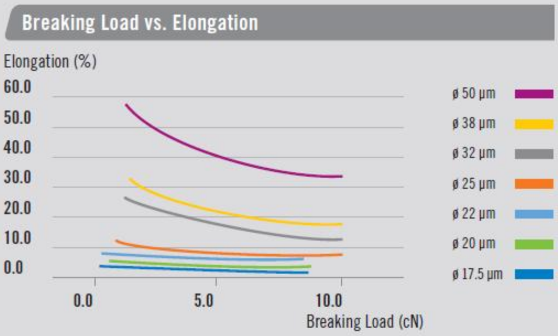
Example:
44 = wire through tool
45 = 45° feed angle
20 = 2 mil feed hole
15 = 1.5 mil foot
¾ = length
F = flat foot

9. Bond-Wire Terms

Size:	Measured in mils (thousands of an inch, or microns, 1 mil 25 microns).
Elongation:	Percentage (%) of stretch of a. length of wire under a given tension. Low % elongation means harder wire.
Material:	Purity of the gold, usually "4 Nines" or 99.99% pure. Can be doped with-Si or Be for strength and/or loop shape forming.
Break Strength:	Tension load at break, for 25µ/1 mil 8 gm is average and 17µ/.7 mil yields 3 gm.
Start Red /Green:	Something you must do. Required to unreel the wire the way it went on the spool. To remove the last wind first of the wire spool.
Wire Tension:	Loading applied to the wire between the wire drag and the bonding tool.

9.1 Gold Wire HD2 Heraeus





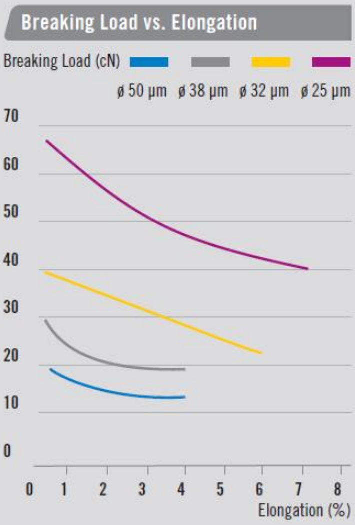
Recommended Technical Data of Au HD2

Diameter	**Microns (µm)**	17.5	20	23	25	30	32	38	50
	Mils	0.7	0.8	0.9	1.0	1.2	1.25	1.5	2.0
Elongation	**%**	2 – 5	2 – 5	2 – 8	2 – 8	2 – 8	2 – 8	3 – 8	3 – 10
Breaking Load	**cN**	> 2,5	> 3	> 5	> 7	> 10	> 11	> 16	> 30

9.2 Aluminum Bonding Wire AlSi 1 % Heraeus

A homogeneous distribution of finely dispersed silicon precipitates achieves a high strength for aluminum wires with diameters < 100 µm. Moreover, the homogeneity of the silicon distribution permits the best processing conditions. The AlSi 1% alloy is also available in the CR variant, which displays particularly corrosion resistant properties.

Areas of application
- Automotive components
- IC cards
- Hybrid components
- Hermetically encapsulated components



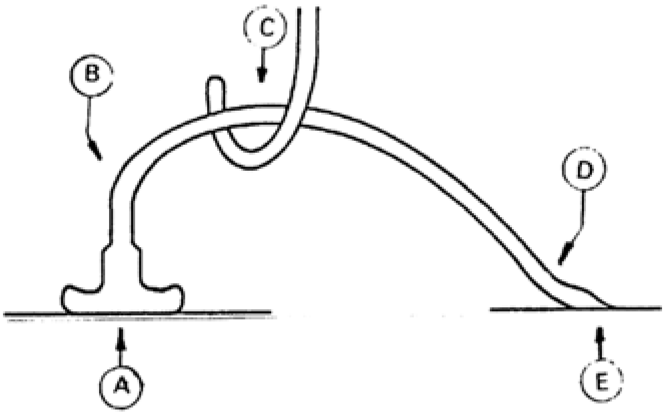
Recommended Technical Data of AlSi 1%

Diameter	**Microns (µm)**	25	30	32	33	38	50	75	100
	Mils	1.0	1.2	1.25	1.3	1.5	2.0	3.0	4.0
Elongation	**%**	> 1	> 1	> 1	> 1	> 1	> 2	> 2	> 2
Breaking Load cN	**hard**	14 – 16	21 – 24	21 – 25	22 – 26	30 – 38	52 – 65	90 – 120	180 – 250
	soft	11 – 14	16 – 21	16 – 21	17 – 22	21 – 30	40 – 52	70 – 90	120 – 180

STORAGE AND SHELF LIFE: Al/Si l% BONDING WIRE MUST BE KEPT SEALED IN THE ORIGINAL PLASTIC BLISTERS AND STORED AT TEMPERATURES OF 15 – 25° C AND A HUMIDITY OF 20 - 50% - THE GUARANTEED SHELF LIFE IS 6 MONTHS FROM THE MANUFACTURING DATE

10. Bond-Pull Strengt Test

The primary method in optimizing the bond schedule is pull strength of the wire as measured by a pull test (i.e., using a gram gauge, hooking the bonded wire, and pulling the wire until failure occurs). A pull test is a relative test for a particular package configuration. Pull strength is dependent upon configuration of the pulling apparatus, the point of attachment of the hook, the level difference between the two weldments, and angle of pull. For absolute values of tensile strength, the pull test should be normalized. When making a pull test, it is important to note where failure occurs - within the lift off failure mode or within the breakage failure mode.



A "Lift Off» first bond

B Wire Break at transition first bond

C Wire Break mid span

D Wire Break at transition second bond

E «Lift Off" second bond

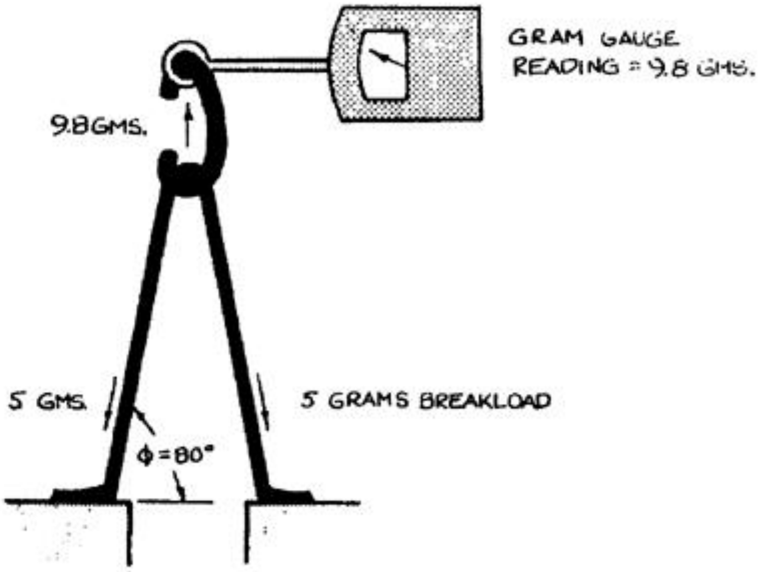
When properly pulled, **the bond should fall at “B” or “D” .** If failures occur at A, C, E, then the bonding parameters, metalisation, bonding machine, bonding tool, hook, has to be reviewed.

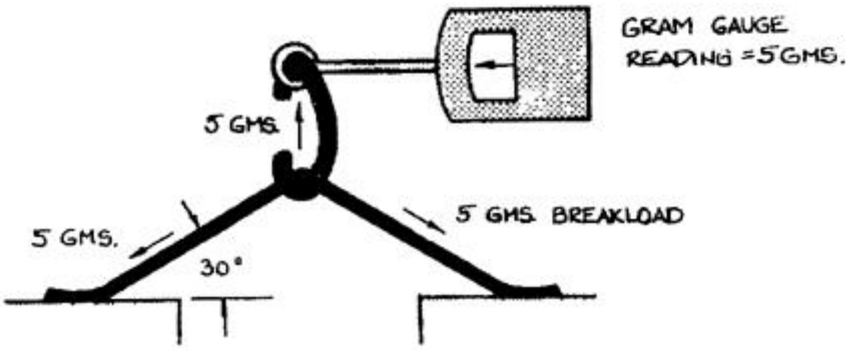
Usually bond pull strength test are made with a gram gauge reading. But the «Gram Gauge Reading» is rearly the real «Breakload» of a bonded wire. Only when ideally both pull angles **first and second bond are pulled at 30°, then “Gram Gauge Reading” = “Breakload”.**

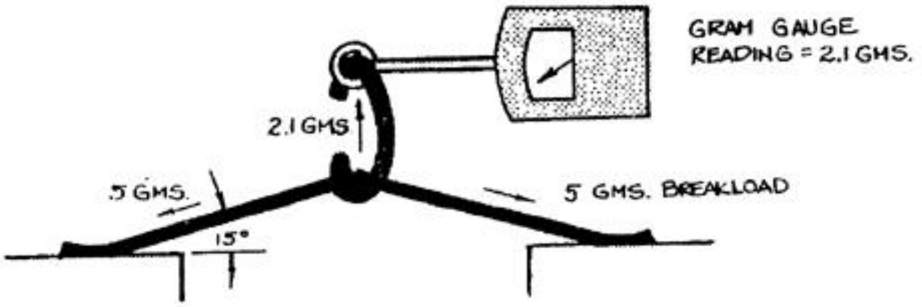
- **Long/high loops will give HIGH Gram Gauge Reading**
- **Short/low loops will give LOW Gram Gauge Reading**

for same real Breakload

Also both first and second bond have to be pulled at same angel, Following bonds are on same level, therefore the hock is placed center between both bonds.





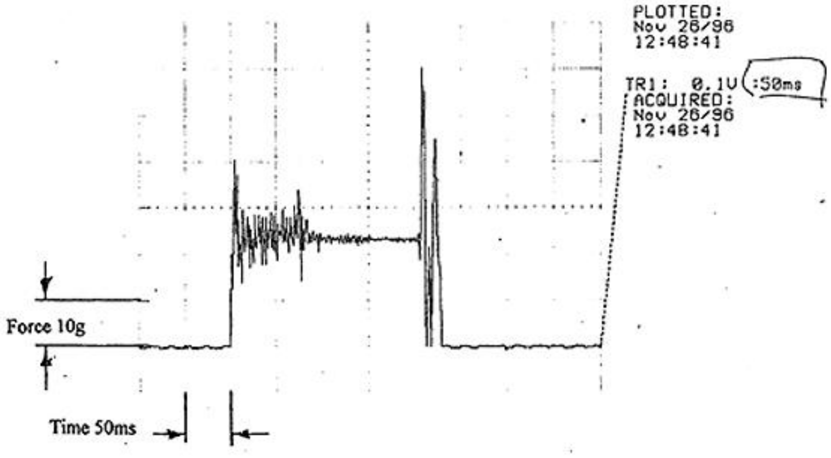


As only the bonds pulled at 30° angle ,
have “Gram Gauge Reading" = “Breakload of Connection".

11. Measuring Bond-Force

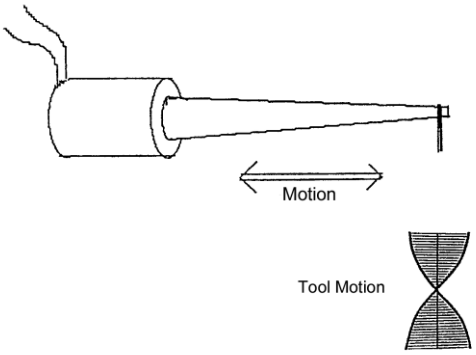
- Statically with a Gram Gage
- Dynamically with a Dynamic Force Sensor

11.1. Measuring Bond-Force with Dynamic Force Sensor



12. Measuring Bond U/S Energy

Transducer Converts Electrical Energy to Mechanical Energy



- OPTICALLY WITH LASER INTERFERUMETER
  The greater the tool vibration amplitude, the greater the energy transmitted to the tool.
- LIGHT CELL FIBER OPTIC SYSTEM
  Measures tool excursion by light reflection.
- ELECTRICALLY AT THE TRANSDUCER INPUT
  Power in minus reflected power equals power transmitted to the tool.

13. Wirebonding Reliability Problems

A. Poor metallization.
B. Variable wire.
C. Improper mounting of chip.
D. Inadequate workholder fixture.
E. Wire bonder variables.
F. Contamination and cleanliness.
G. Oxides on wire and chip.
H. Chuck or workholder must hold part rigid.

14. Wire Problems

Good wire and capillaries are essential for the production of reliable devices.

- **Gold Wire** will self anneal on the shelf in as little time as three months, stabilized gold (Beryllium doped) might last as long as six months. Keep wire in N2 storage.

- **Aluminum Wire** - The 1-2% silicon wire will let the silicon migrate into clumps of hard silicon rich segments over a time of six month. Keep wire in N2 storage.

- **Wire Spools** should be stored with axes horizontal to minimize wire shifting on spools.

These recommendations are equally valid for both Al/l% Si and Au bonding wire. Inconsistent bonding is a predictable consequence of improper storage, or excessively long storage.

15. Capillary / Wedge Selection

Selection of the proper capillary/Wedge should be based on application data, which entails:

a. *Device (die)*
Metallization
Pad Dimensions
Accessibility to Stitch - 2nd Bond

b. *Bonding Machine*
Automatic / Manuel Bonder
Thermosonic Ball / Wedge Bonding

C. *Wire*
Material
Diameter
Elongation
Tensile Strength

16. Ball-Bonding Problems

16.1 Large ball under-deformed. The contact area is too small and the bond is too thick.
  a) excessive size of prebonded ball.
  b) excessive wire size.
  c) insufficient force andlor power setting.

16.2 Large Ball Bond ,The ball bond is too large for a small pad.
  a) excessive size of prebonded ball.
  b) excessive wire size.
  c) excessive force and/or power setting.

16.3 Off centerigolf club shaped ball bond can be caused by:
  a) inside chamfer is too small or incorrect angle
  b) wire is too hard
  c) wire tension/drag is not tight enough
  d) incorrect vertical distance between the electrode and the end of the wire.
  e) excessive tall length.

16.4 Necking above the ball bond can occur for several reasons:
  a) Insufficient force on the tool allowing the ball to wobble during scrubbing
  b) Free-air ball size too small, which is captured within the inside chamfer
  c) Incorrect percent elongation of the wire allowing the wire to work harden during ball formation

17. Wedge & Ball-Bonding Problems

17.1 - Cratering of Bond Pad

  a) Bond head is dropping too fast against bond pad, causing excessive tool impact on the die pad. This is due to excessive bond head force and / or excessive search height.
  b) Excessive power setting.
  c) Work piece movement during bonding.
  d) Poor adhesion of metallization to active device. (Note: This is not true cratering.)
  e) Bond time too long
  f) Bond stage temp is too high
  h) Bond pad metalization is too hard and/or thin

17.2 Wedge / Ball not sticking to Bond Pad

a) excessive size of prebonded ball.
b) Tool not square to workpiece
c) residual silicon oxide or contamination on the bonding pad.
d) pre-bonded ball size too small, which is captured within the inside chamfer.
e) Poor plating or metallization.
f) Organic contamination.
g) Lead or package not clamped rigidly, allowing the lead to move during scrubbing.
h) Lead surface not parallel to tool face.
i) Improper power or force setting.
j) Defective, worn or dirty bonding tool.
k) Bonding to downwards slope of substrate metalization such that the tool touches work but wire does not.
l) One or any combination of the following:
    Force too low
    Time too short
    Ultrasonics too low or high
    Temperature too high or low

17.3 Sagging or wavy wires

a) use of small wire diameter for a long loop length.
b) use of high elongation wire.
c) excessive drag due to: small hole size, too small or damaged inside chamfer.

17.4 Tight Loop

a) low elongation wire (stiff).
b) the vertical distance from ball to stitch is much greater than the horizontal distance.

17.5 Scratching of wire

a) wire from the spool has scratches
b) wire clamp surface damaged.
c) damaged inside chamfer.
d) wire clamp gap not open.
e) excessive wire drag.

17.6 Tailing (wire breaks in Bondtool)

a) Very good bond-ability of metalization.
b) Inside chamfer angle is too shallow.
c) Inside chamfer size is too large.
d) Excessive wire elongation factor.
e) Wire is too old.

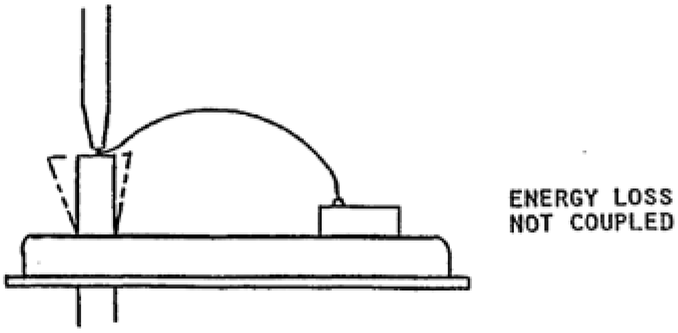
17.7 No Tail after second Bond (Wire Stuck in Wire Hole of Bond Tool)

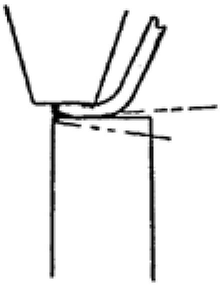
- a) Overbonding at second bond due to one or any combination of the following:
    - Tail length set too low
    - Too much wire pull
    - Force too high
    - Time too long
    - Ultrasonics too high
    - Dirty bonding tool.
- b) Bonding on downwards slope of substrate metalization such that only wire touches the work, applying excessive force.
- c) Loose workpiece.
- d)Clamp force adjustment incorrect.
- e) Not pulling Tail after second Bond (wire not attached to Workpiece)
- f) Clamps not closing, tail length adjustment incorrect.
- g) Clamps closing but wire slipping through clamps, clamp force adjustment incorrect.
- h) Clamp surfaces contaminated.
- i) Clamp surfaces not parallel due to darnaged clamp assembly.

17.8 Pulling up second bond, but not breaking wire after second Bond

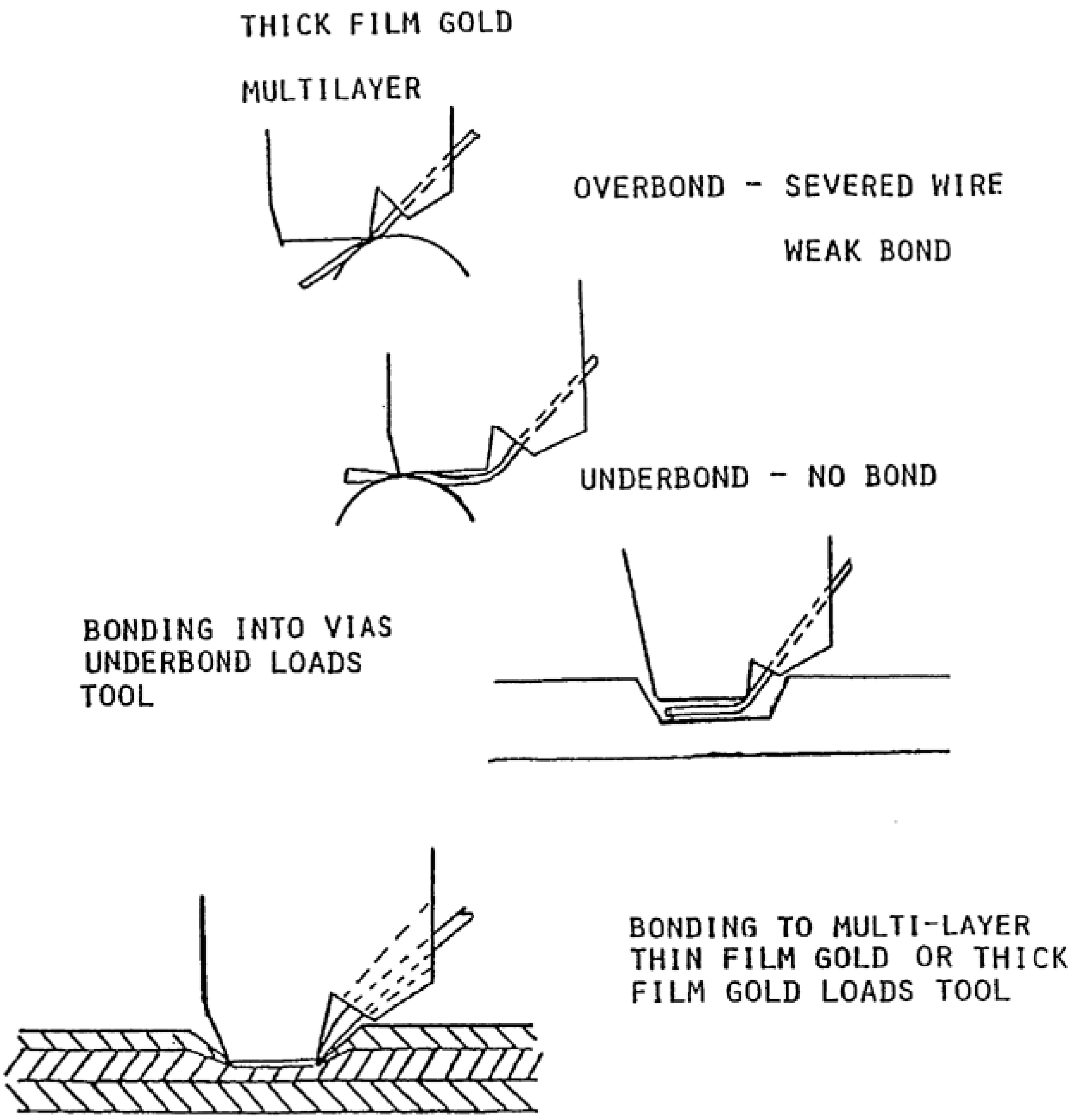
- a) Force too low
- b) Time too short
- c) Ultrasonics too low

18. Pin Bonding Problem





19. Irregular Surface Problem / Ball & Wedge -Bonding

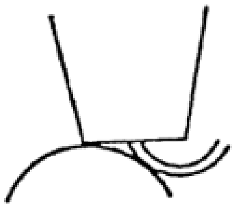


19.1. Irregular Surface Problem / Ball & Wedge-Bonding

THICK FILM GOLD

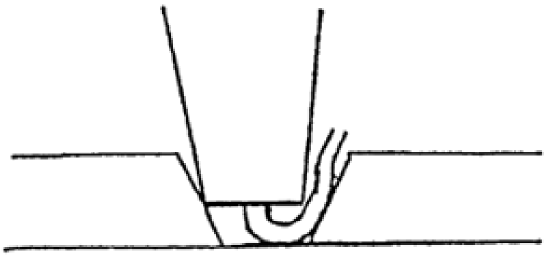
MULTILAYER

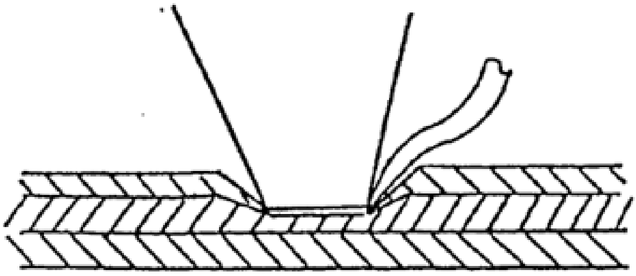
OVERBOND – SEVERED WIRE
JAM OR PLUG TOOL
WEAK BOND



UNDERBOND – NO BOND

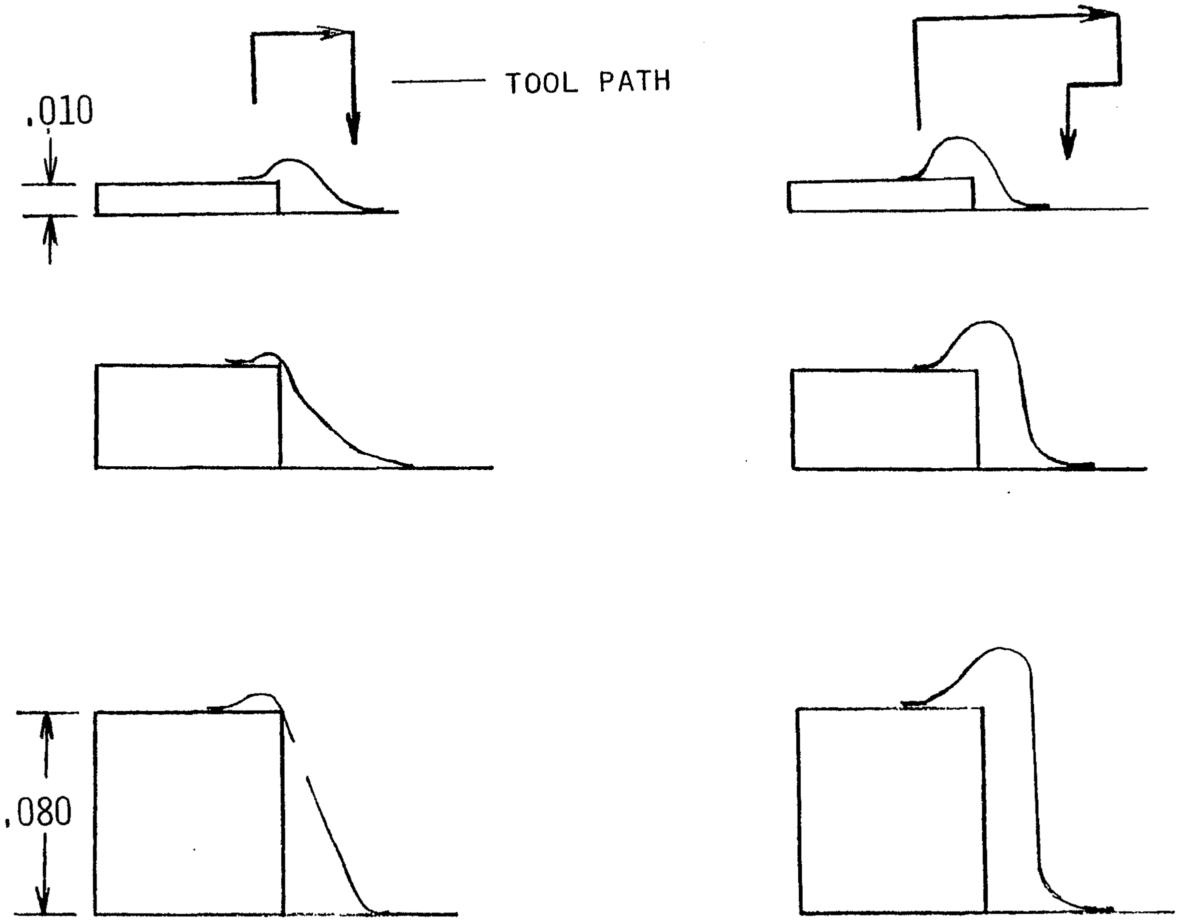
BONDING INTO VIAS
UNDERBOND
SCRUB FROM
TOOL SIDE LOAD





BONDING TO MULTI-LAYER
THIN FILM GOLD CAUSES
TOOL PLUGGING

20. Loop Problem / Step-Bonding forming a Loop



21. MIL-STD 883 Specification for Visual Bond Inspection

Reasons for ACCEPT or REJECT decision:

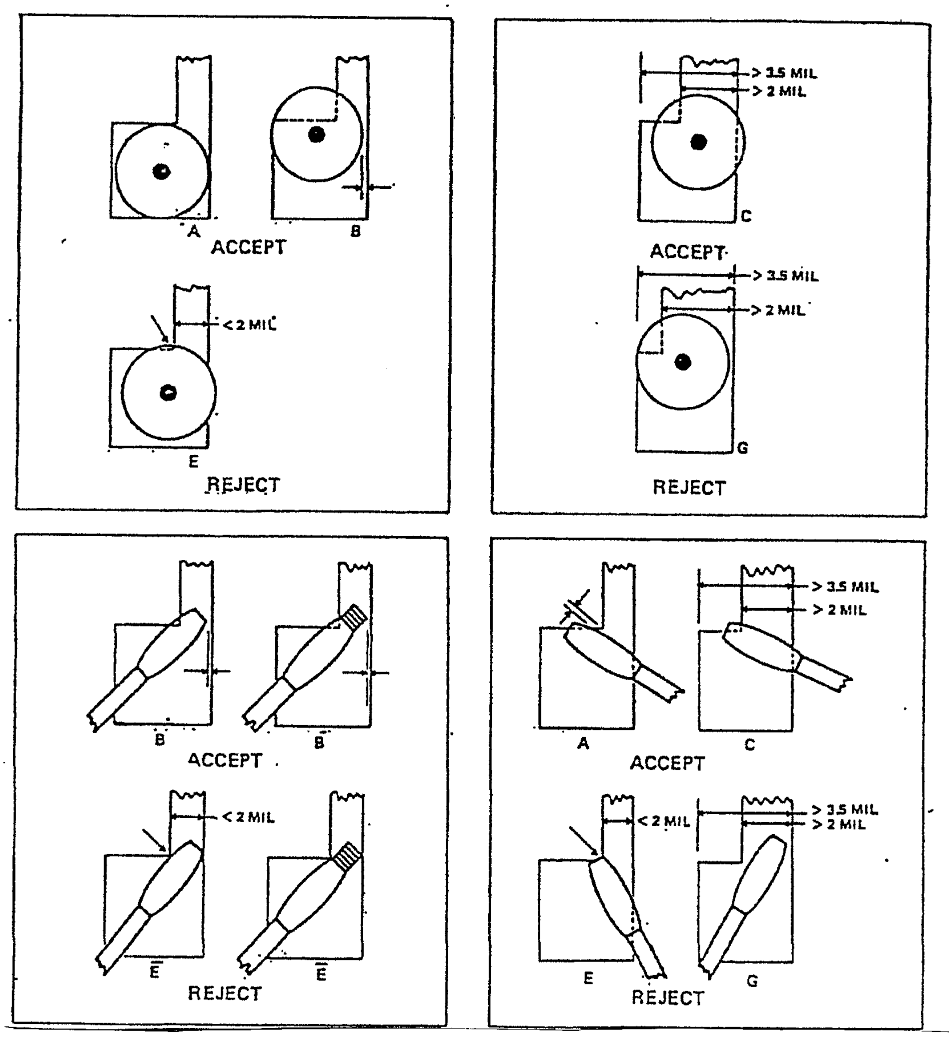
A: ACCEPT, because > 75% of the bond area is on the bonding pad, and there is no bond at the point where metal exits from the bonding pad

B: ACCEPT, because >75% of the bond area is on the bonding bad, and there is no visible line of undisturbed connecting metal between the bond periphery and at least one side of the entering metal

C: ACCEPT, even though no visible line of connecting metal exists, since the entering metal width is >2 mils and the bonding pad dimension is >3,5 mils on the entering metal side, and >75% of the bond area is on the bonding pad.

E: REJECT, due to a bond at the point where metal exits from the bonding pad without a visible line of connecting metal, and the entering metal width is not >2 mils (bond-tail are considered part of the bond for Condition A).

G: REJECT, due to a bond area <75% on the bonding pad even though all other criteria are met.



22. Glossary of Terms

ANGLED BOND	Bond impression of first and second bond are not in a straight line.
ASSEMBLY -	A hybrid circuit which includes discrete or integrated components that have been attached. It might also mean the assembly of more than one such circuits on individual substrates.
ASSEMBLY DRAWING	A drawing showing a circuit with its components and interconnections mounted or soldered to the -film network, and in their proper position. It might also show the assembly of more than one circuits of a given device prior packaging/sealing.
BACK BONDING	Bonding active chips to the substrate using the back of the chip, leaving the face, with -its circuitry face up. The opposite of back bonding is face down bonding.
BALL BOND	A bond formed when a ball shaped end interconnecting wire is deformed by thermocompression against a metallized pad. The bond is also designated a nail head bond from the appearance of the flattened ball.
BACK RADIUS	The radius of the trailing edge of bonding tool.
BOND	An interconnection which performs a permanent electrical and/or mechanical function.
BOND AREA	The area defined by the extent of a metallization bonding pad on die or surface of leads to which the wire is to be bonded.
BOND DEFORMIATION	The change in the form of the lead produced by the bonding tool, causing plastic flow, in making the bond.
BOND FORCE	Used to promote plastic flow (Deformation) and intimate coupling between the bonding tool, the wire, and the workpiece. Measured in grams.
BOND INTERFACE	The interface between the lead and the material to which it was bonded on the substrate.
BOND LIFT-OFF -	The failure mode whereby the bonded lead separates from the surface to which it was bonded.
BOND SCHEDULE -	The values of the bonding machine parameters used when adjusting for bonding. For example, in ultrasonic bonding, the values of the bonding force, time, and ultrasonic power.

BOND SHEAR STRENGTH	In hybrids, it is to be calculated as limiting stress, measured as a true shear force (in grams or newtons) applied uniformly along the complete length of an items side or contour, moving parallel to the bond interface and divided by the sheared-off bond surface area. Applicable to shearing a substrate from a package bottom, or a die or device from a substrate surface.
BOND STRENGTH	In wire bonding, the pull force at rupture of the bond interface measured in the unit gram-force.
BONDABILITY -	Those surface characteristics and conditions of cleanliness of a bonding area which must exist in order to provide a capability for successfully bonding an interconnection Material by one of several methods, such as ultrasonic or thermo -compression wire bonding.
BONDING, DIE -	Attaching the semiconductor chip to the substrate, either with an epoxy, eutectic or solder alloy.
BONDING AREA -	The area, defined by the extent of a metallization land or the top surface of the terminal, to which a lead is or is to be bonded.
BONDING PAD	A metallized area at the end of a metallic conductive trace to which a connection is to be made.
BONDING WIRE	Fine gold or aluminium wire (lightly doped, usually) for making electrical connections in hybrid circuits between various bonding pads on the semiconductor device substrate and device terminals or substrate lands.
BURN-IN	The process of electrically stressing a device (usually at an elevated temperature environment) for an adequate period of time to cause failure of marginal devices.
CAPILLARY	A hollow bonding tool used to guide the bonding wire and to apply pressure to the wire during -the bonding cycle.
CHESSMAN	The disk, knob, or lever used to manually control the position of the bonding tool with respect to the substrate.
CHIP	The uncased and normally leadless form of an electronic component part, either passive or active, discrete or integrated.
CHIP-AND-WIRE	A hybrid technology employing face-up-bonded chip devices exclusively, interconnected to the substrate conventionally.
CHIPOUT -	A discontinual defect along the edge of a semiconductor or a ceramic substrate; damage caused by inadvertent mechanical impact, most often due to careless handling.

CRATERING	Defect in which a portion of the die chips under ultrasonic bonding, by excessive amounts of energy. (Chip out).
CLEAN ROOM	A special manufacturing area where the air is filtered to remove dust particles and precautionary measures are used to keep contamination away from the unprotected circuit during processing.
CERAMIC -	Inorganic nonmetallic material such as alumina, berylia, steatite, or forsterite, whose final characteristics are produced by subjection to high temperatures, often used in microelectronics as parts of components, substrate, or package.
COVER SEAL	It denotes the seal at the perimeter of the cover or lid, when joined to the package body; or, in hybrid fabrication, the cover-sealing operation itself. The seal may be accomplished by resistance welding, cold weld (solid-phase bond), brazing, soldering, or by other -means.
CUSTOM HYBRID	A hybrid integrated microcircuit device, designed by or for a particular customer, and fabricated on a hybrid production line, dedicated at the time to satisfying the contract with that customer. The term is used as opposed to "commercial hybrid IC" , generally produced in volume.
DEVICE	A single discrete electronic element such as a transistor or resistor, or a number of elements integrated within one die, which cannot be further reduced or divided without eliminating its stated function. Preferred usage is die or dice, bare, or pre-packaged.
DIE BOND -	Attachment of a die or chip to the hybrid substrate.
DIE-SHEAR STRENGTH	The effective die-Shear strength is the measured true shear force (for example, in grams) applied parallel with the plane of the substrate with uniform distribution against the complete length of the bonded die's edge, via a linear motion flat contact tool and sufficient to shear the die off its mounting, when divided by the area of the sheared-off surface. Choice of units: grams/mil ; kg/inch ; psi ; or newtons/inch .
FIRST BOND	This first bond in a sequence of two or more bonds made to form a conductive connection.
FOOT LENGTH	The long dimension of the bonding surface of a wedge-type bonding tool.
FOOT PRINT -	The area needed on a substrate for a component or element. Usually refers to specific geometric pattern of a chip.
GANG BONDING	The act of bonding a plurality of mechanical and/or electrical connections through a single act or stroke or a bonding tool.

HYBRID CIRCUIT	A microcircuit consisting of elements which are a combination of the film circuit type and the semiconductor circuit type, or a combination of one or both of these types and may include discrete add-on components.
JUMPER -	A direct electrical connection between two points on a film circuit. Jumpers are usually portions of bare or insulated wire mounted on the component side of the substrate.
KIRKENDALL VOIDS	The formation of voids by diffusion across interface of two different materials.
LOOP HEIGHT	Formed by the wire between the attachment points (die to lead). Also, a measure of deviation wire height, known as loop height.
METALLIZATION	The metal film (single or multilayer) on the bonding pads which is to be electrically connected with wire.
OVER BONDING	Bonds that are of excessive deformation such to greatly reduce bonding strength. (Low pull test).
PULL STRENGTH	The amount of force (measured in grams) required to break bond loop wire. Pull test performed on loop at a point perpendicular to bond pad.
PURPLE PLAGUE	An inter-metallic compound of gold and aluminum from high temp bonding T/C.
SEARCH HEIGHT	The height of the wire bonding tool above the die and lead, which final adjustments are made before bonding.
SECOND BOND	Made on your lead or bonding pad of substrates.
STITCH BOND	A bond between the first bond and the terminating bond along a length of wire used to interconnect more then two points.
TRANSDUCER	Supplying ultrasonic vibrations to make bonds.
ULTRASONIC BONDING	A process using Gold or Aluminum wire to join two Materials together using US energy, time and force.
ULTRASONIC POWER	Electronic high frequency generator provides ultrasonic energy to the transducer.

23. Recommended Books :

Advanced Wirebond Interconnection Technology, Shankara K. Prasad, 2004,
Kluwer Academic Publishers, ISBN 1-4020- 7762-9

Wire Bonding in Microelectronics, Materials, Processes, Reliability and Yield, Georg Harman,
Second Edition, 1997, McGraw-Hill Verlag, ISBN 0-07-032619-3