Automotive Electronics Council
Component Technical Committee

ATTACHMENT 1

AEC - Q100-001 REV-C

WIRE BOND SHEAR TEST

Acknowledgment

Any document involving a complex technology brings together experience and skills from many sources. The Automotive Electronics Counsel would especially like to recognize the following significant contributors to the development of this document:

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Change Notification

The following summary details the changes incorporated into AEC-Q100-001 Rev-C:

- **Section 1.3.4.4, Type 4 - Die Surface Contact: Corrected wording to reflect bond shear type where the shear tool contacts the die surface, rather than the bonding surface as stated in Rev - B.**

- **Added new Section 1.3.5, Footprint: Added new definition for "footprint"; changed numbers of subsequent sections to reflect the addition.**

- **Section 3.6 step b, Footprint Inspection of Aluminum Wedge/Stitch Bonds: Added wording to clarify method used to remove wire for footprint inspection.**

- **Figure 3, Wire Bond Shear Types: Updated figure to reflect wording correction made to Type 4 - Die Surface Contact.**

- **Minor wording changes were made to the following: Section 1.1, 1.3.1, 1.3.4.1, 1.3.4.5, 2.2, 2.5, 3.2, and 3.5.**

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METHOD - 001

WIRE BOND SHEAR TEST

Text enhancements and differences made since the last revision of this document are shown as underlined areas. Several figures have also been revised, but changes to these areas have not been underlined.

1. SCOPE

1.1 Description

This test establishes a procedure for determining the strength of the interface between a gold ball bond and a package bonding surface, or an aluminum wedge/stitch bond and a package bonding surface, on either pre-encapsulation or post-encapsulation devices. This strength measurement is extremely important in determining two features:

1) the integrity of the metallurgical bond which has been formed.

2) the reliability of gold and aluminum wire bonds to die or package bonding surfaces.

This test method can be used only when the ball height and diameter for ball bonds, or the wire height (1.25 mils and larger at the compressed bond area) for wedge/stitch bonds, are large enough and adjacent interfering structures are far enough away to allow suitable placement and clearance (e.g., above the bonding surface and between adjacent bonds) when performing the wire bond shear test.

The wire bond shear test is destructive. It is appropriate for use in process development, process monitoring, and/or quality assurance.

1.2 Reference Documents

Not Applicable

1.3 Terms and Definitions

The terms and definitions shall be in accordance with the following sections.

1.3.1 Ball Bond

The welding of a thin wire, usually gold, to a die bonding surface, usually an aluminum alloy bond pad, using a thermal compression or thermosonic wire bonding process. The ball bond includes the enlarged spherical portion of the wire (sometimes referred to as the nail head and formed by the flame-off and first bonding operation in thermal compression and thermosonic process), the underlying bonding surface, and the intermetallic weld interface. For the purposes of this document, all references to ball bonds are applicable to gold ball bonds on die bonding surfaces; other ball bond material combinations may require a new set of failure criteria (see section 4.1).

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1.3.2 Bonding Surface

Either 1) the die surface (e.g., die bond pad) or 2) the package bonding surface (e.g., plated leadframe post or finger, downbond to the flag or paddle, etc.) to which the wire is ball, wedge, or stitch bonded.

1.3.3 Bond Shear

A process in which an instrument uses a chisel shaped tool to shear or push a ball or wedge/stitch bond off the bonding surface (see Figure 1). The force required to cause this separation is recorded and is referred to as the bond shear strength. The bond shear strength of a gold ball bond, when correlated to the diameter of the ball bond, is an indicator of the quality of the metallurgical bond between the gold ball bond and the die bonding surface metallization. The bond shear strength of an aluminum wedge/stitch bond, when compared to the manufacturer's bond wire tensile strength, is an indicator of the integrity of the weld between the aluminum wire and the die or package bonding surface.

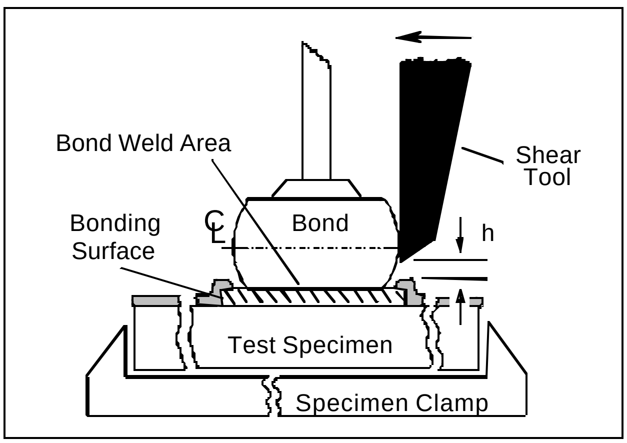


Figure 1: Bond Shear set-up

1.3.4 Definition of Bond Shear Types for Ball and Wedge/Stitch Bonds (see Figure 3)

1.3.4.1 Type 1 - Bond Lift

A separation of the entire wire bond from the bonding surface with only an imprint being left on the bonding surface. There is very little evidence of intermetallic formation or welding to the bonding surface metallization.

1.3.4.2 Type 2 - Bond Shear

A separation of the wire bond where: 1) A thin layer of bonding surface metallization remains with the wire bond and an impression is left in the bonding surface, or 2) Intermetallics remain on the bonding surface and with the wire bond, or 3) A major portion of the wire bond remains on the bonding surface.

1.3.4.3 Type 3 - Cratering

A condition under the bonding surface metallization in which the insulating layer (oxide or interlayer dielectric) and the bulk material (silicon) separate or chip out. Separation interfaces which show pits or depressions in the insulating layer (not extending into the bulk) are not considered craters. It should be noted that cratering can be caused by several factors including the wire bonding operation, the post-bonding processing, and even the act of wire bond shear testing itself. Cratering present prior to the shear test operation is unacceptable.

1.3.4.4 Type 4 - Die Surface Contact

The shear tool contacts the die surface and produces an invalid shear value. This condition may be due to improper placement of the specimen, a die surface not parallel to the shearing plane, a low shear height, or instrument malfunction. This bond shear type is not acceptable and shall be eliminated from the shear data.

1.3.4.5 Type 5 - Shearing Skip

The shear tool removes only the topmost portion of the ball or wedge/stitch bond. This condition may be due to improper placement of the specimen, a die surface not parallel to the shearing plane, a high shear height, or instrument malfunction. This bond shear type is not acceptable and shall be eliminated from the shear data.

1.3.4.6 Type 6 - Bonding Surface Lift

A separation between the bonding surface metallization and the underlying substrate or bulk material. There is evidence of bonding surface metallization remaining attached to the ball or wedge/stitch bond.

1.3.5 Footprint

An impression of the compressed wedge/stitch bond area created in the bonding surface during the ultrasonic wire bonding process. The bond footprint area is normally larger than the actual metallurgical weld interface.

1.3.6 Shear Tool or Arm

A tungsten carbide, or equivalent, chisel with specific angles on the bottom and back of the tool to insure a shearing action.

1.3.7 Wedge/Stitch Bond

The welding of a thin wire, usually aluminum, to a die or package bonding surface using an ultrasonic wire bonding process. The wedge bond, sometimes referred to as a stitch bond, includes the compressed (ultrasonically bonded) area of the bond wire and the underlying bonding surface. When wedge/stitch bonding to an aluminum alloy bonding surface, no intermetallic exists because the two materials are of the same composition; but rather the two materials are combined and recrystallized by the ultrasonic energy of the welding process. For the purposes of this document, all references to wedge/stitch bonds are applicable to aluminum wedge/stitch bonds only; gold wedge/stitch bonds are not required to be wire bond shear tested.

2. APPARATUS AND MATERIAL

The apparatus and materials required for wire bond shear testing shall be as follows:

2.1 Inspection Equipment

An optical microscope system or scanning electron microscope providing a minimum of 30X magnification.

2.2 Measurement Equipment

An optical microscope or measurement system capable of measuring the wire bond diameter to within ± 0.1 mil.

2.3 Workholder

Fixture used to hold the device being tested parallel to the shearing plane and perpendicular to the shear tool. The fixture shall also eliminate device movement during wire bond shear testing. If using a caliper controlled workholder, place the holder so that the shear motion is against the positive stop of the caliper. This is to insure that the recoil movement of the caliper controlled workholder does not influence the wire bond shear test.

2.4 Wire Bond Shear Equipment

The wire bond shear equipment must be capable of precision placement of the shear tool approximately 0.1 mil above the topmost part of the bonding surface. This distance (h) shall insure the shear tool does not contact the die or package bonding surface and shall be less than the distance from the topmost part of the bonding surface to the center line (C_L) of the ball or wedge/stitch bond.

2.5 Bond Shear Tool

Required shear tool parameters include but are not limited to: flat shear face, sharp shearing edge, and shearing width of 1.5 to 2 times (1.5X to 2X) the bond diameter or bond length. The shear tool should be designed to prevent plowing and drag during wire bond shear testing. The shear tool should be clean and free of chips (or other defects) that may interfere with the wire bond shear test.

3. PROCEDURE

3.1 Calibration

Before performing the wire bond shear test, it must be determined that the equipment has been calibrated in accordance with the manufacturer's specifications and is presently in calibration. Recalibration is required if the equipment is moved to another location.

3.2 Visual Examination of Wire Bonds to be Shear Tested After Decapsulation

Before performing wire bond shear testing on a device which has been opened using wet chemical and/or dry etch techniques, the bonding surfaces shall be examined to insure there is no absence of metallization on the bonding surface area due to chemical etching. Ball or wedge/stitch bonds on bonding surfaces with evidence of degradation from chemical attack or absence of metallization shall not be used for wire bond shear testing. Wire bonds on bonding surfaces without degradation from chemical attack may not be attached to the bonding surface due to other causes (e.g., package stress). These wire bonds are considered valid and shall be included in the shear data as a zero (0) gram value. Wire bonds must also be examined to ensure adjacent interfering structures are far enough away to allow suitable placement and clearance (above the bonding surface and between adjacent wire bonds) when performing the wire bond shear test.

3.3 Measurement of the Ball Bond Diameter to Determine the Ball Bond Failure Criteria

Once the bonding surfaces have been examined and prior to performing wire bond shear testing, the diameter of all ball bonds (from at least one representative sample to be tested) shall be measured and recorded. For asymmetrical ball bonds, determine the average using both the largest (d_{large}) and the smallest diameter (d_{small}) values (see Figure 2). These ball bond diameter measurements shall be used to determine the mean, or average, diameter value. The resulting mean, or average, ball bond diameter shall then be used to establish the failure criteria as defined in section 4.1. If process-monitor data has established the nominal ball bond diameter, then that value may be used to determine the failure criteria as defined in section 4.1.

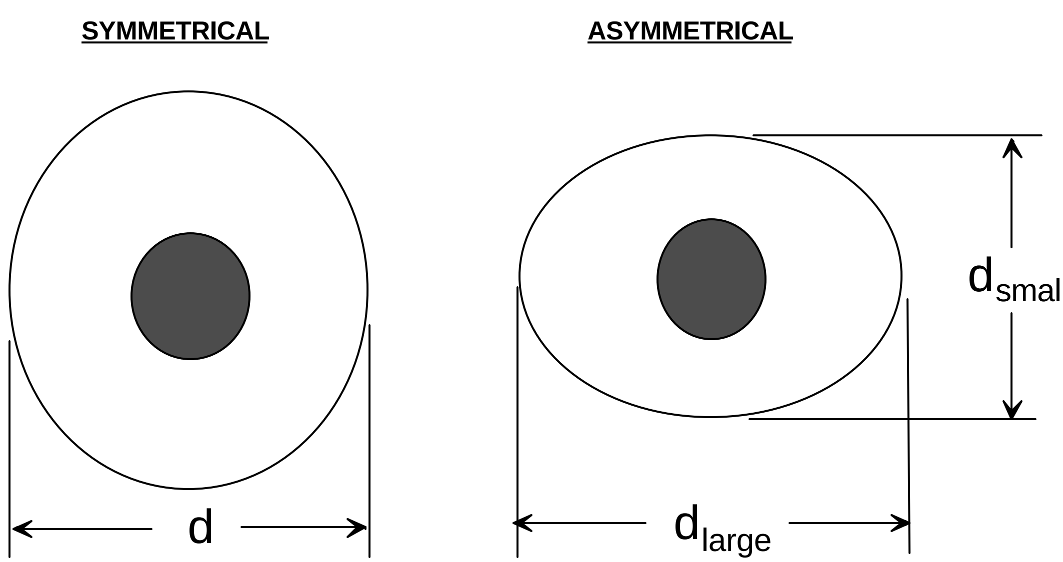


Figure 2: Ball bond diameter measurement (symmetrical vs. asymmetrical)

3.4 Wire Bond Shear Test Procedure

The wire bond shear testing procedure shall be performed as follows:

a. The wire bond shear equipment shall pass all self diagnostic tests prior to performing the wire bond shear test.

b. The wire bond shear equipment and test area shall be free of excessive vibration or movement. Examine the shear tool to verify it is in good condition and is not bent or damaged. Check the shear tool to verify it is in the up position.

c. Adjust the workholder to match the device being tested. Secure the device to the workholder. Make sure the die or package bonding surface is parallel to the shearing plane of the shear tool. It is important that the shear tool does not contact the bonding surface or adjacent structures during the shearing operation as this will give incorrect high readings.

d. Position the device so that the wire bond to be tested is located adjacent to the shear tool. Lower the shear tool (or raise the device depending upon wire bond shear equipment used) to approximately the die or package bonding surface but not contacting the surface (approximately the thickness of the wire bond above the die or package bonding surface).

e. For ball bond shear testing, position the ball bond to be tested so that the shear motion will travel perpendicular to the die edge. Wire bond shear testing is required for ball bonds located at the die bonding surface interface only.

f. For aluminum wedge/stitch bond shear testing, a wire height at the compressed bond area of 1.25 mils and larger is required. For wires too small for wire bond shear testing (less than 1.25 mils in height at the compressed bond area), only a footprint inspection is required (see section 3.6). Position the wedge/stitch bond to be tested so that the shear motion will travel toward the long side of the wedge/stitch bond and is free of any interference (i.e. shear the outside wedge/stitch bond first and then shear toward the previously sheared wedge/stitch bond). Wire bond shear testing is required for aluminum wedge/stitch bonds located at die and package bonding surfaces; gold wedge/stitch bonds are not required to be wire bond shear tested.

g. Position the shear tool a distance of approximately one ball bond diameter (or one aluminum wire diameter for wedge/stitch bonds) from the wire bond to be shear tested and shear the wire bond.

3.5 Examination of Sheared Wire Bonds

All wire bonds shall be sheared in a planned/defined sequence so that later visual examination can determine which shear values should be eliminated due to an improper shear. The wire bonds shall be examined using at least 30X magnification to determine if the shear tool skipped over the wire bond (type 5) or the shear tool scraped or plowed into the die surface (type 4). See Figure 3 for bond shear types and illustrations.

Readings in which either a bond shear type 4 or 5 defective shear condition occurred shall be eliminated from the shear data. Bond shear type 1, 2, 3, and 6 shall be considered acceptable and included in the shear data.

Sheared wire bonds in which a bond shear type 3 cratering condition has occurred shall be investigated further to determine whether the cracking and/or cratering is due to the wire bonding process or the act of wire bond shear testing. Cratering caused prior to the wire bond shear test operation is unacceptable. Cratering resulting from the act of wire bond shear testing shall be considered acceptable and included in the shear data.

3.6 Footprint Inspection of Aluminum Wedge/Stitch Bonds

a. All aluminum wire bonding processes to both die and package bonding surfaces shall have a bond footprint inspection performed.

b. For wires too small for wire bond shear testing (less than 1.25 mils in height at the compressed bond area), the wires shall be removed at the wedge/stitch bond location using a small sharp blade <u>to peel or pluck the wire bond from the bonding surface</u>. The removal of the aluminum wire shall be sufficient such that the wire bond interface can be visually inspected and the metallurgical wire bond area determined.

c. For larger wires (greater than 1.25 mils in height at the compressed bond area), the wires shall be inspected after wire bond shear testing to examine the failure mode and to determine the wedge/stitch bond footprint coverage.

3.7 Bond Shear Data

Data shall be maintained for each wire bond sheared. The data shall identify the wire bond (location, ball bond and/or wire diameter, wire material, method of bonding, and material bonded to), the shear strength, and the bond shear type (as defined in section 1.3.4 and Figure 3).

4. FAILURE CRITERIA

The following failure criteria are not valid for devices that have undergone environmental stress testing or have been desoldered from circuit boards.

4.1 Failure Criteria for Gold Ball Bonds

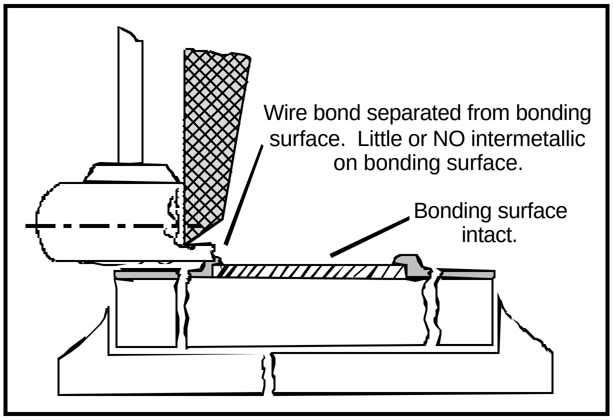
The gold ball bonds on a device shall be considered acceptable if the minimum individual and sample average ball bond shear values are greater than or equal to the values specified in Figure 4 and Table 1. This criteria is applicable for gold wire ball bonds on aluminum alloy bonding surfaces. Other material combinations may require a new set of failure criteria.

Alternate minimum ball bond shear values may be proposed by the supplier if supporting data justifies the proposed minimum values.

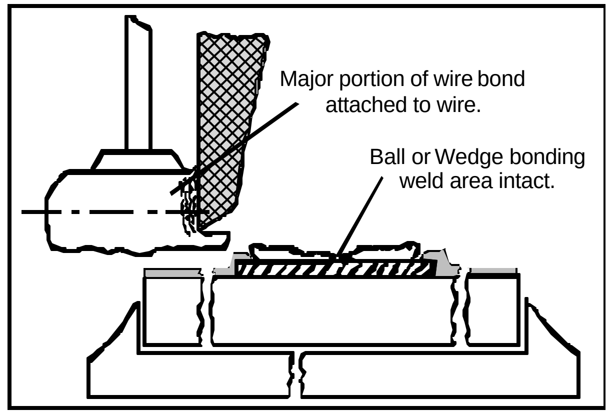
4.2 Failure Criteria for Aluminum Wedge/Stitch Bonds

The aluminum wedge/stitch bonds on a device shall be considered acceptable if the minimum shear values are greater than or equal to the manufacturer's bond wire tensile strength.

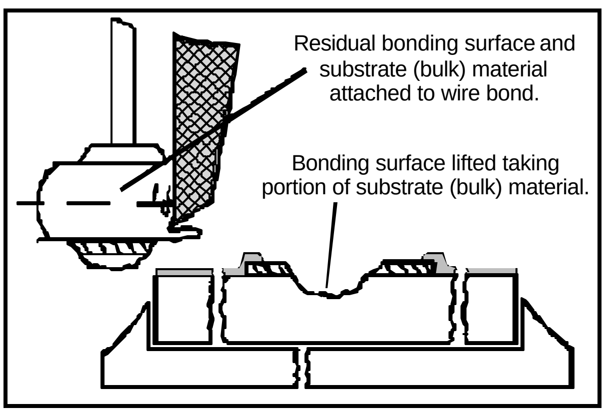
In addition, the percent of the wedge/stitch bond footprint in which bonding occurs shall be greater than or equal to 50%. If it is necessary to control the wire bonding process using SPC for percent coverage, a C_{pk} value can be calculated to this limit.



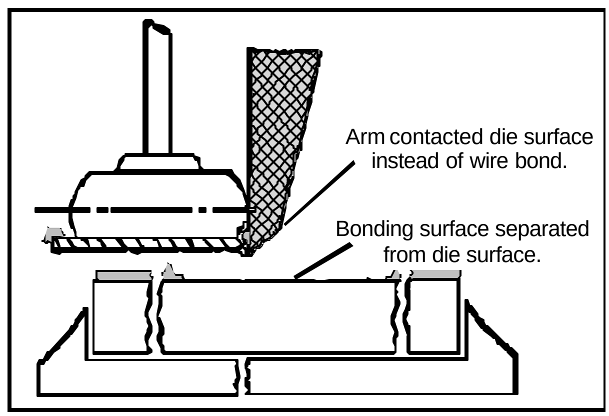
TYPE 1: Bond Lift



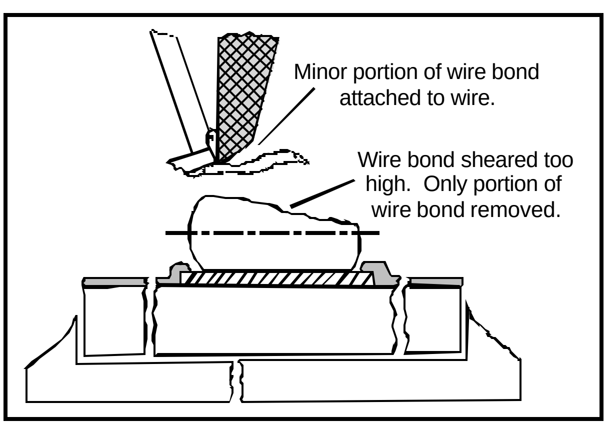
TYPE 2: Bond Shear - Gold/Aluminum



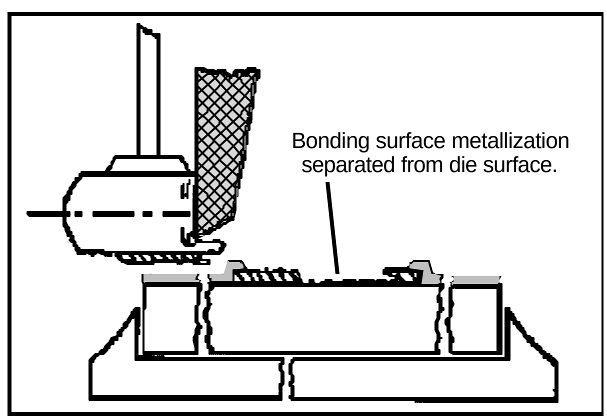
TYPE 3: Cratering



TYPE 4: Die Surface Contact



TYPE 5: Shearing Skip



TYPE 6: Bonding Surface Lift

Figure 3: Wire Bond Shear Types *

*** (Shear types are illustrated using ball bonds; these types also apply to wedge/stitch bonds)**

MINIMUM SHEAR VALUES

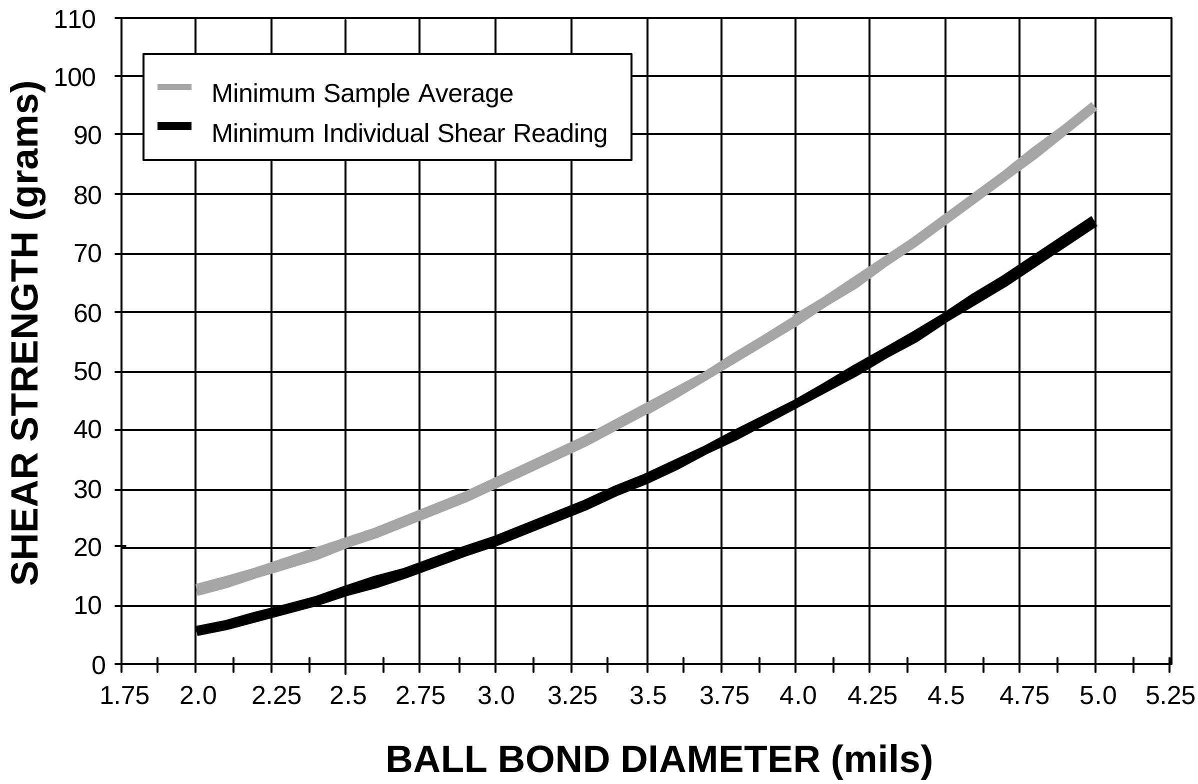


Figure 4: Minimum acceptable individual and sample average ball bond shear values *, see Table 1 for exact ball bond shear values *

*** (Shear values are applicable for gold wire ball bonds on aluminum alloy bonding surfaces)**

Table 1: Minimum acceptable individual and sample average ball bond shear values *

*** (Shear values are applicable for gold wire ball bonds on aluminum alloy bonding surfaces)**

Ball Bond Diameter (mils)	Minimum Sample Average (grams)	Minimum Individual Shear Reading (grams)
2.0	12.6	5.7
2.1	14.0	6.8
2.2	15.5	8.1
2.3	17.1	9.5
2.4	18.8	10.9
2.5	20.6	12.4
2.6	22.4	14.0
2.7	24.4	15.6
2.8	26.5	17.4
2.9	28.6	19.2
3.0	30.8	21.1
3.1	33.2	23.1
3.2	35.6	25.1
3.3	38.1	27.2
3.4	40.7	29.4
3.5	43.4	31.7
3.6	46.2	34.1
3.7	49.1	36.5
3.8	52.1	39.1
3.9	55.2	41.7
4.0	58.3	44.3
4.1	61.6	47.1
4.2	65.0	50.0
4.3	68.4	52.9
4.4	71.9	55.8
4.5	75.6	59.0
4.6	79.3	62.1
4.7	83.1	65.3
4.8	87.0	68.6
4.9	91.0	72.0
5.0	95.1	75.5

Revision History

Rev #	Date of change	Brief summary listing affected sections
-	June 9, 1994	Initial Release.
A	May 19, 1995	Added copyright statement.
B	Sept. 6, 1996	Deleted old Sections 1.3.4, 1.3.5, 3.3, 3.9, and 5.0. Added new Sections 1.3.1, 1.3.2, 1.3.6, 3.4 (steps a through g), and 3.6 (steps a through c). Revised the following: Sections 1.1, 1.2, 1.3.1, 1.3.2, 1.3.3, 1.3.4 (1.3.4.1 through 1.3.4.6), 1.3.5, 1.3.6, 2.1, 2.2, 2.4, 2.5, 3.1, 3.2, 3.3, 3.4 (a, b, c, d, e, f, and g), 3.5, 3.6 (a, b, and c), 3.7, 4.0, 4.1, and 4.2; Table 1; Figures 1, 3, and 4.
C	Oct. 8, 1998	Added new Section 1.3.5. Revised the following: Sections 1.1, 1.3.1, 1.3.4.1, 1.3.4.4, 1.3.4.5, 2.2, 2.5, 3.2, 3.5, 3.6 (b), Figure 3.