



Designation: **F72–17 F72 – 17<sup>ε1</sup>**

# Standard Specification for Gold Wire for Semiconductor Lead Bonding<sup>1</sup>

This standard is issued under the fixed designation F72; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reappraisal. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reappraisal.

<sup>ε1</sup> NOTE—In 9.3.1, the reference to Test Methods E16 was corrected to Test Methods F16 editorially in March 2020.

## 1. Scope

1.1 This specification covers round drawn/extruded gold wire for internal semiconductor device electrical connections. Four classifications of wire are distinguished, (1) copper-modified wire, (2) beryllium-modified wire, (3) high-strength wire, and (4) special purpose wire.

NOTE 1—Trace metallic elements have a significant effect upon the mechanical properties and thermal stability of high-purity gold wire. It is customary in manufacturing to add controlled amounts of selected impurities to gold to modify or stabilize bonding wire properties, or both. This practice is known variously as “modifying,” “stabilizing,” or “doping.” The first two wire classifications denoted in this specification refer to wire made with either of two particular modifiers, copper or beryllium, in general use. In the third and fourth wire classifications, “high-strength” and “special purpose” wire, the identity of modifying additives is not restricted.

1.2 The values stated in SI units shall be regarded as the standard.

1.2.1 A mixed system of metric and inch-pound units is in widespread use for specifying semiconductor lead-bonding wire. SI-equivalent values of other commonly used units are denoted by parentheses in text and tables.

1.3 The following hazard caveat pertains only to the test method portion, Section 9, of this specification. *This standard does not purport to address all of the safety, health, and environmental safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

## 2. Referenced Documents

2.1 *ASTM Standards:*<sup>2</sup>

**E16**<sup>F16</sup> **Method of Free Bend Test for Ductility of Welds Test Methods for Measuring Diameter or Thickness of Wire and Ribbon for Electronic Devices and Lamps** (Withdrawn 1978)

**F205** **Test Method for Measuring Diameter of Fine Wire by Weighing**

**F219** **Test Methods of Testing Fine Round and Flat Wire for Electron Devices and Lamps**

**F584** **Practice for Visual Inspection of Semiconductor Lead-Bonding Wire** (Withdrawn 2015)<sup>3</sup>

## 3. Ordering Information

3.1 Orders for material under this specification shall include the following information:

3.1.1 Classification: copper-modified, beryllium-modified, high strength, or special purpose,

3.1.2 Quantity,

3.1.3 Purity (Section 4),

3.1.4 Type, hard, stress relieved, or annealed (Section 5),

3.1.5 Breaking load and percentage elongation range (Section 5),

3.1.6 Wire diameter (Section 6),

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee F01 on Electronics and is the direct responsibility of Subcommittee F01.03 on Metallic Materials, Wire Bonding, and Flip Chip.

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard’s Document Summary page on the ASTM website.

<sup>3</sup> The last approved version of this historical standard is referenced on www.astm.org.

- 3.1.7 Spool type, length of wire per spool, and type of wind (Section 11),
- 3.1.8 Despooling, left-handed unwind or right-handed unwind (Section 11), and,
- 3.1.9 Packaging and marking (Section 12).

#### 4. Chemical Composition

- 4.1 Beryllium-modified material shall conform to the chemical requirements specified in Table 1.
- 4.2 High-strength material shall conform to the chemical requirements specified in Table 2.
- 4.3 Special purpose material shall be in accordance with Table 3.

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**TABLE 1 Chemical Requirements, Beryllium-Modified Gold Bonding Wire**

Element	Composition, Weight, %
Gold, min	99.99
Beryllium	0.0003–0.0010
Other impurities, max each	0.003
Total of all detectable impurities, max	0.01

**TABLE 2 Chemical Requirements, High-Strength Gold Bonding Wire**

Element	Composition, Weight, %
Gold, min	99.99
Total of all detectable impurities, max	0.01

**TABLE 3 Chemical Requirements, Special Purpose Gold Bonding Wire**

Element	Composition, Weight, %
Gold	Not restricted
Other principal elements	Not restricted
Total of all detectable elements	Not restricted

NOTE 2—Copper-modified wire is used on thermocompression wire bonding machines. Beryllium-modified material is often preferred on high-speed automated thermocompression or thermosonic bonding equipment. High-strength wire was developed for use on some very high speed automated thermosonic bonders.

## 5. Mechanical Properties

5.1 Material specified by this standard may be either of two types:

5.1.1 *Hard*—Wire, as drawn/as extruded.

5.1.2 *Annealed*—Wire, annealed after drawing/extruding.

5.2 *Breaking Load and Elongation*—The tension test shall be the standard test for determining the mechanical properties, and acceptance or rejection shall depend on the breaking load and percent elongation at failure of a 254-mm (10.0-in.) length of wire.

5.2.1 Hard wire shall conform to the requirements of [Table 4](#) for beryllium-modified gold wire.

5.2.2 Stress relieved/annealed wire shall conform to the requirements of [Table 5](#) for beryllium-modified gold wire, to the requirements of [Table 6](#) for high-strength wire, and to the requirements of [Table 7](#) for special purpose wire.

NOTE 3—Hard wire is generally used for ultrasonic wire bonding. Annealed wire is used for thermocompression and thermosonic bonding.

## 6. Dimensions and Permissible Variations

6.1 Wire diameters shall be expressed in  $\mu\text{m}$  (or equivalent decimal fractions of an inch). Tolerances for the various size ranges are specified in [Table 8](#).

## 7. Workmanship, Finish, and Appearance

7.1 The wire surface shall be clean and free of finger oils and stains.

7.2 The wire surface shall be free of drawing/extrusion lubricant residues, particulate matter and other contaminants that would interfere with functional performance of the wire. The seller and the purchaser must agree upon acceptable standard of surface cleanliness.

7.3 The surface shall be free of surface contamination that would degrade service life of the device to which it is attached. The seller and the purchaser must agree upon acceptable standard of surface cleanliness.

7.4 The wire surface shall be free of nicks, dents, scratches, or other blemishes deeper than 5 % of the wire diameter. The surface shall be free of flaws protruding more than 5 % of the wire diameter above the surface.

**TABLE 4 Breaking Load and Elongation of Hard Wire—Beryllium-Modified Gold and High-Strength Gold<sup>A</sup>**

Nominal Diameter, $\mu\text{m}$ (in.)	Breaking Load, min, N (gf)	Elongation in 254 mm (10.0 in.), %
13 (0.00050)	0.039 (4.0)	0.5 to 2.0, incl
18 (0.00070)	0.069 (7.0)	0.5 to 2.0, incl
20 (0.00080)	0.088 (9.0)	0.5 to 2.0, incl
23 (0.00090)	0.147 (15.0)	1.0 to 2.5, incl
25 (0.0010)	0.177 (18.0)	1.0 to 2.5, incl
28 (0.0011)	0.216 (22.0)	1.0 to 2.5, incl
30 (0.0012)	0.265 (27.0)	1.0 to 2.5, incl
31.8 (0.00125)	0.284 (29.0)	1.0 to 2.5, incl
33 (0.0013)	0.314 (32.0)	1.0 to 2.5, incl
38 (0.0015)	0.392 (40.0)	1.0 to 2.5, incl
51 (0.0020)	0.736 (75.0)	1.0 to 3.0, incl

<sup>A</sup> All modern wires are expected to have a somewhat longer shelf life, but each manufacturer's product will be slightly different.

**TABLE 5 Breaking Load and Elongation of Stress Relieved/  
Annealed Wire—Beryllium-Modified Gold<sup>A</sup>**

Nominal Diameter, $\mu\text{m}$ (in.)	Breaking Load, min, N (gf)	Elongation in 254 mm (10.0 in.), %		
		Min	Max	Range <sup>B</sup>
13 (0.00050)	0.020 (2.0)	0.5	3.0	2
18 (0.00070)	0.029 (3.0)	0.5	7.0	3
20 (0.00080)	0.039 (4.0)	0.5	8.0	3
23 (0.00090)	0.059 (6.0)	0.5	8.0	3
25 (0.0010)	0.069 (7.0)	0.5	10.0	3
28 (0.0011)	0.078 (8.0)	0.5	10.0	3
30 (0.0012)	0.0981 (10.0)	0.5	10.0	3
31.8 (0.00125)	0.108 (11.0)	0.5	10.0	3
33 (0.0013)	0.118 (12.0)	0.5	10.0	3
38 (0.0015)	0.147 (15.0)	0.5	12.0	4
51 (0.0020)	0.245 (25.0)	0.5	15.0	4

<sup>A</sup> All modern wire are expected to have a somewhat longer shelf life, but each manufacturer's product will be slightly different.

<sup>B</sup> A range of permissible elongation of at least the number of percentage points shown shall be selected from within the overall range designated by the minimum and maximum values for the given diameter. For example, for wire of 25- $\mu\text{m}$  (0.0010-in.) diameter, permissible elongation of 4.0 to 7.0, 6.0 to 9.0, 7.0 to 10.0 %, etc., may be selected.

**TABLE 6 Breaking Load and Elongation of Stress Relieved/  
Annealed Wire—High-Strength Gold<sup>A</sup>**

Nominal Diameter, $\mu\text{m}$ (in.)	Breaking Load, min, N (gf)	Elongation in 254 mm (10.0 in.), % <sup>B</sup>	
		Min	Max
13 (0.00050)	0.020 (2.0)	0.5	3.0
18 (0.00070)	0.039 (4.0)	0.5	5.0
20 (0.00080)	0.040 (5.0)	0.5	6.0
23 (0.00090)	0.064 (6.5)	0.5	6.0
25 (0.0010)	0.078 (8.0)	0.5	6.0
28 (0.0011)	0.093 (9.5)	0.5	6.0
30 (0.0012)	0.113 (11.5)	0.5	6.0
31.8 (0.00125)	0.123 (12.5)	0.5	6.0
33 (0.0013)	0.132 (13.5)	0.5	6.0
38 (0.0015)	0.176 (18.0)	0.5	7.0
51 (0.0020)	0.314 (32.0)	0.5	7.0

<sup>A</sup> All modern wire are expected to have a somewhat longer shelf life, but each manufacturer's product will be slightly different.

<sup>B</sup> Except for 13  $\mu\text{m}$ , 38  $\mu\text{m}$ , and 51  $\mu\text{m}$ , the minimum-maximum range is usually 3 percentage points, for example, 2 to 5, 3 to 6, and 4 to 7 %. For 13  $\mu\text{m}$  it is usually 1.5 percentage points, for example, 0.5 to 2, 1 to 2.5, and 1.5 to 3 %. For 38  $\mu\text{m}$  and 51  $\mu\text{m}$  it is usually 4 percentage points, for example, 0.5 to 4.5, 1 to 5, 2 to 6, and 3 to 7 %.

7.5 The wire shall despool without excessive curl that would degrade functional performance. The seller and the purchaser must agree upon acceptable amount of curl. Curl is measured by the springback test (9.5).

7.6 The wire must be free of twist about the wire axis. Referring to wire twist test procedure (9.6), wire entwining upon itself one or more complete turns (9.6.5.4) is rejectable by the purchaser. Lesser degrees of twist may be acceptable, as agreed upon between seller and purchaser.

7.7 The wire cross section must not be out-of-round to such an extent that functional performance is impaired. The seller and the purchaser must agree upon acceptable amount of out-of-roundness.

NOTE 4—It is the intention of the directly responsible Subcommittee, F01.07, that the term “functional performance” be narrowly construed as follows: wire imperfections denoted in 7.2, 7.5, and 7.7 must not be of sufficient severity to excessively impair the operation of an otherwise normally functioning wire bonding machine. In practice, standards of adequate “functional performance” vary considerably, depending upon application.

## 8. Sampling

8.1 Unless otherwise agreed, conformance with Section 5 shall be determined by samples from each lot of wire.

8.2 *Lot Sampling*—A lot shall consist of all material from one melt or bar in a shipment against one order description.

8.3 *Sampling Plan*:

**TABLE 7 Breaking Load and Elongation of Stress Relieved/  
Annealed Wire-Special Purpose<sup>A</sup>**

Nominal Diameter, $\mu\text{m}$ (in.)	Breaking Load, min, N (gf)	Elongation in 254 mm (10.0 in.), %		
		Min	Max	Range <sup>B</sup>
13 (0.00050)	To be determined between wire user and wire manufacturer	0.5	3.0	1.5
18 (0.00070)		0.5	7.0	2.0
20 (0.00080)		0.5	8.0	2.0
23 (0.00090)		0.5	8.0	2.0
25 (0.0010)		0.5	10.0	2.0
28 (0.0011)		0.5	10.0	2.0
30 (0.0012)		0.5	10.0	2.0
31.8 (0.00125)		0.5	10.0	2.0
33 (0.0013)		0.5	10.0	2.0
38 (0.0015)		0.5	12.0	2.0
51 (0.0020)		0.5	15.0	2.0

<sup>A</sup> All modern wire are expected to have a somewhat longer shelf life, but each manufacturer's product will be slightly different.

<sup>B</sup> A range of permissible elongation of at least the number of percentage points shown shall be selected from within the overall range designated by the minimum and maximum values for the given diameter. For example, for wire of 25- $\mu\text{m}$  (0.0010-in.) diameter, a permissible elongation of 4.0 to 6.0, 6.0 to 8.0, 7.0 to 9.0 %, etc., may be selected.

**TABLE 8 Dimensional Tolerances**

Nominal Diameter, $\mu\text{m}$ (in.)	Standard Tolerance		Special Purpose Tolerance	
	% of Nominal Diameter	% of Nominal Weight	% of Nominal Diameter	% of Nominal Weight
13 (0.00050)	$\pm 6$	$\pm 15$	+6/-2	+1/-10
Over 13 to 25 (over 0.0005 to 0.0010), incl	$\pm 3$	$\pm 10$	+6/-2	+1/-6
Over 25 to 51 (over 0.0010 to 0.0020)	$\pm 3$	$\pm 6$	+3/-0.5	+1/-4

8.3.1 A spool of wire used for testing may not be useful for production. Choose a sampling plan that will permit scrapping of test spools as gold wire, particularly of small diameter, is easily damaged.

8.3.2 Select the number of spools that will give a representative sampling, as agreed upon between the purchaser and the seller.

#### 8.4 Number of Samples:

8.4.1 Take samples from not less than 1 % of the spools from each lot.

8.4.2 Take not less than three samples from each spool.

### 9. Test Methods

9.1 *Chemical Requirements*—Perform chemical analysis using an emission spectrograph or other method having equivalent sensitivity. Cross-check individual constituents (for example, copper or beryllium) by using atomic absorption spectrometric or other appropriate quantitative analytical method. The seller and the purchaser must agree upon analytical techniques to be employed.

9.2 *Breaking Load and Elongation*—Apply the tension test in accordance with Test Methods **F219**.

9.3 *Wire Diameter*—Measure the wire diameter by one of the following methods:

9.3.1 Measure the diameter directly with apparatus and procedure in accordance with Test Methods **E16F16**. Because annealed gold wire is very soft, exercise caution when using the direct-measurement method to prevent deformation of the wire.

9.3.2 Measure the wire diameter indirectly by weighing in accordance with Test Method **F205**.

9.3.2.1 When the weight determination method is used, the following values shall be employed: gold density—19.34 g/cm<sup>3</sup>; weight of a 200-mm length of wire of 25.4- $\mu\text{m}$  (0.00100-in.) diameter—1.96 mg.

9.3.2.2 *Calculation of Diameter from Weight*—When gold wire is weighed in 200-mm lengths, calculate the diameter as follows:

$$D (\mu\text{m}) = \sqrt{(W/1.96)} \times 25.4$$

$$D (\text{in}) = \sqrt{(W/1.96)} \times 0.001$$

where:

$D$  = diameter, and  
 $W$  = mass, mg/200 mm.

9.4 *Finish:*

- 9.4.1 *Visual Examination*—Perform visual examination using an optical binocular microscope in accordance with Practice F584.
- 9.4.2 Use a scanning electron microscope to determine the depth of surface blemishes.

9.5 *Wire Curl Test:*

9.5.1 This test should be regarded as destructive. After the wire is despoiled to perform the test, the remainder of the wire on the spool will generally be too disturbed for use.

9.5.2 Test must be performed in a well-lighted work area free of air drafts.

9.5.3 *Equipment*—A fixture capable of supporting wire spool with its axis horizontal, and that permits the spool to rotate freely about its axis; metre stick; fine tweezers suitable for holding wire end (see Fig. 1).

9.5.4 Arrange the equipment as indicated schematically in Fig. 1. Refer to Fig. 1 in performing the steps that follow.

9.5.5 *Procedure:*

9.5.5.1 Mount spool on fixture.

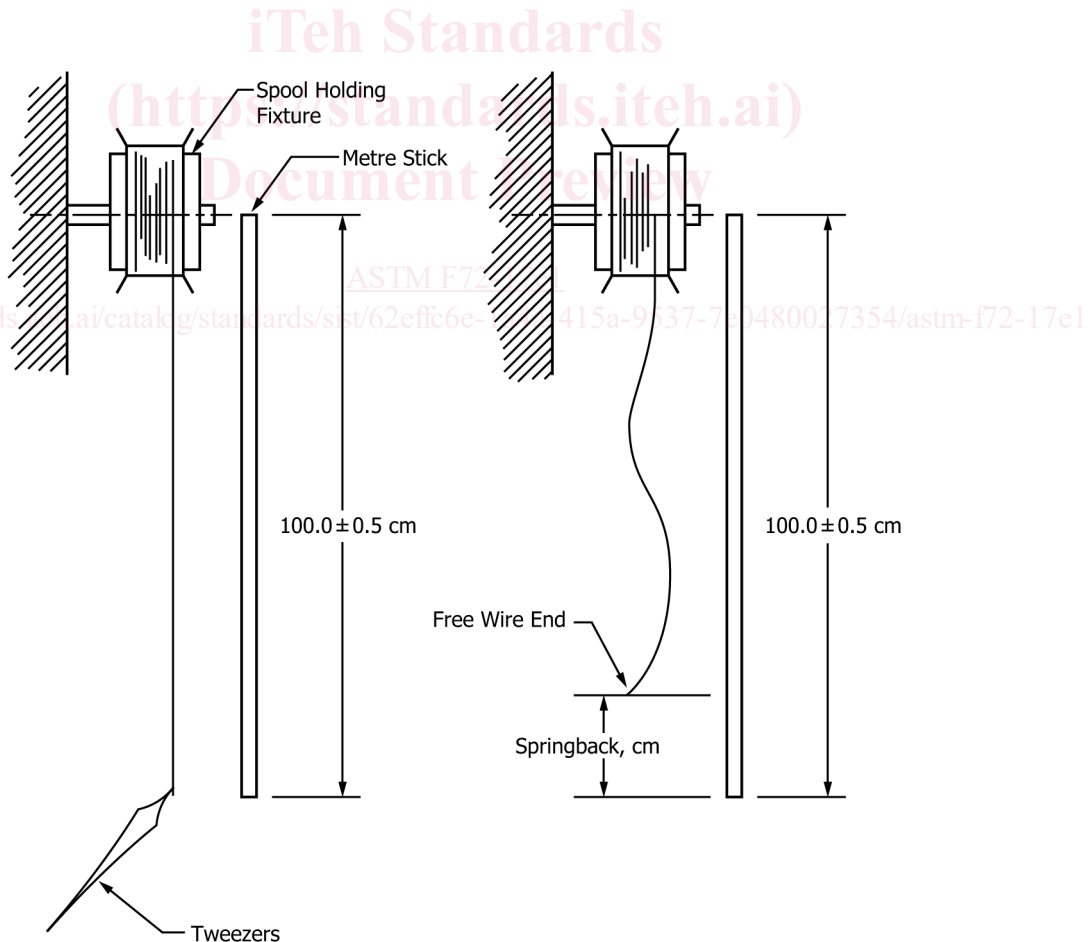
9.5.5.2 Using the tweezers, break the “starting end” wire end from its securing tab (Section 11). Gently pull the wire end, thus rotating the spool and dereeling the wire. Pulling force must not exceed 30 % of the wire breaking load. Pull the free wire end downward until  $100 \pm 0.5$  cm of wire has been despoiled. Use the metre stick as a gage.

9.5.5.3 Release the wire end.

9.5.5.4 Measure the vertical springback of the free wire end, again using the metre stick as a gage.

9.5.5.5 The curl is defined as the springback determined in 9.5.5.4, measured in millimetres.

9.6 *Wire Axial Twist Test:*



(a) 100 cm Wire Dereeled from Spool

(b) Free End of Wire Released, Showing Springback

FIG. 1 Test Arrangement, Wire Curl Test