SLOVENSKI STANDARD
oSIST prEN IEC 60749-22-1:2025

01-februar-2025

Polprevodniški elementi - Metode za mehansko in klimatsko preskušanje - 22-1. del: Moč vezi - Preskusne metode za vlečenje žične vezi

Semiconductor devices - Mechanical and climatic test methods - Part 22-1: Bond strength - Wire bond pull test methods

Ta slovenski standard je istoveten z: **prEN IEC 60749-22-1:2024**

ICS:

31.080.01	Polprevodniški elementi (naprave) na splošno	Semiconductor devices in general

oSIST prEN IEC 60749-22-1:2025 **en**

47/2888/CDV

COMMITTEE DRAFT FOR VOTE (CDV)

PROJECT NUMBER: **IEC 60749-22-1 ED1**	
DATE OF CIRCULATION: **2024-12-13**	CLOSING DATE FOR VOTING: **2025-03-07**
SUPERSEDES DOCUMENTS: **47/2883/RR**	

IEC TC 47 : SEMICONDUCTOR DEVICES	
SECRETARIAT: Korea, Republic of	SECRETARY: Mr Cheolung Cha
OF INTEREST TO THE FOLLOWING COMMITTEES:	HORIZONTAL FUNCTION(S):
ASPECTS CONCERNED:	
☐ SUBMITTED FOR CENELEC PARALLEL VOTING	☒ NOT SUBMITTED FOR CENELEC PARALLEL VOTING

This document is still under study and subject to change. It should not be used for reference purposes.
Recipients of this document are invited to submit, with their comments, notification of any relevant patent rights of which they are aware and to provide supporting documentation.

Recipients of this document are invited to submit, with their comments, notification of any relevant “In Some Countries” clauses to be included should this proposal proceed. Recipients are reminded that the CDV stage is the final stage for submitting ISC clauses. (SEE AC/22/2007 OR NEW GUIDANCE DOC).

TITLE:

Semiconductor devices - Mechanical and climatic test methods - Part 22-1: Bond strength - wire bond pull test methods

PROPOSED STABILITY DATE: 2031

NOTE FROM TC/SC OFFICERS:

CONTENT

INTERNATIONAL ELECTROTECHNICAL COMMISSION

_____

SEMICONDUCTOR DEVICES – MECHANICAL AND CLIMATIC TEST METHODS –

Part 22-1: Bond strength - wire bond pull test methods

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

IEC 60749-22-1 has been prepared by IEC technical committee 47: Semiconductor devices. It is an International Standard.

This first edition together with the first edition of IEC 60749-22-2, cancels and replaces IEC 60749-22 published in 2002 and is based on JEDEC document JESD22-B120. It is used with permission of the copyright holder, JEDEC Solid State Technology Association.

This edition includes the following significant technical changes with respect to the previous edition:

Major update, including new techniques and use of new materials (e.g. copper wire) involving a complete rewrite as two separate subparts (this document and IEC 60749-22-2)

The text of this International Standard is based on the following documents:

Draft	Report on voting

XX/XX/FDIS	XX/XX/RVD

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

SEMICONDUCTOR DEVICES – MECHANICAL AND CLIMATIC TEST METHODS –

PART 22-1: BOND STRENGTH - WIRE BOND PULL TEST METHODS

1 Scope

This test method provides a means for determining the strength and failure mode of a wire bonded to, and the corresponding interconnects on, a die or package bonding surface and may be performed on unencapsulated or decapsulated devices. This test method may be performed on gold alloy, copper alloy, and silver alloy thermosonic (ball and stitch) bonds made of wire ranging in diameter from 15 µm to 76 µm (0,000 6” to 0,003”); and on gold alloy, copper alloy, and aluminium alloy ultrasonic (wedge) bonds made of wire ranging in diameter from 18 µm to 600 µm (0,000 7” to 0,024”)

This wire bond pull test method is destructive. It is appropriate for use in process development, process control, and/or quality assurance.

This test method allows for two distinct methods of pulling wires:

1) One method incorporates the use of a hook that is placed under the wire and is then pulled.
2) One method requires that after the wire be cut, a clamp is placed on the wire connected to the bond to be tested, and this clamp is used to pull the wire.

This test method defines three pull tests. The Wire Pull Test (WPT) is appropriate for all bonded wires. The Ball Pull Test (BPT) and Stitch Pull Test (SPT) are appropriate for thermosonically bonded wires.

This test method can also be used on the following four applications of thermosonic and ultrasonic bonds, though each requires special considerations when performing the test method:

a) Pulling aluminium wires and aluminium ribbons that are bonded with multiple ultrasonic bonds. See 5.3.2.2.2 for special considerations. Multiloop wires and ribbons are used in some high-power device packages.
b) Pulling wires of reverse bonds which are also known as “stitch on ball”. These types of bonds can include gold stitch on gold ball, copper stitch on copper ball, and copper stitch on gold ball. See Clause A.1 in Annex A for additional information.
c) Pulling a thermosonically bonded wire that has a security bond (see 3.9) or security loop (see 3.19) placed on top of the stitch bond (see 3.3) in order to provide additional strength. See Clause A.2 for additional information.
d) Pulling thermosonic wire bonds on stacked die when wires and/or bonds are not accessible to allow for proper pull testing. See 5.3.2.2.4 for special considerations

This test method does not include bond strength testing using wire bond shear testing. Wire bond shear testing is described in IEC 60749-22-2, Bond strength testing – Wire bond shear test methods.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies.

IEC 60749-22-2, *Semiconductor devices – Mechanical and climatic test methods – Part 22-2: Bond strength testing – Wire bond shear test methods.*

For undated references, the latest edition of the referenced document (including any amendments) applies.

Also see Bibliography (informative) references.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1
bond, wire
adhesion or welding of a wire (typically gold, aluminium, copper, or silver) to a bonding surface using a thermosonic or ultrasonic wire bonding process.

3.2
ball, bond
first bond during the thermosonic (ball) bonding process, in which the end of a small diameter wire (typically gold, copper, or silver) is bonded to a die bonding surface (typically an aluminium alloy die pad metallization).

Note 1 to entry: The ball bond includes the enlarged spherical or nail-head portion of the wire that is provided by the electronic flame-off, the underlying bonding pad, and the metallurgical weld interface between the ball bond and the bonding pad.

3.3
stitch bond
second bond during the thermosonic (ball) bonding process, in which the wire is typically bonded to the package bonding surface (e.g., leadframe, substrate, post, etc.).

Note 1 to entry: A stitch bond may also be referred to as a crescent bond

Note 2 to entry: For some unique constructions (e.g., reverse bond), the second bond may be formed on top of a bump. See also “reverse bond” and “bump”).

3.4
wedge bond
attachment of a wire (typically aluminium, copper, or gold) or an aluminium ribbon to a die bonding surface (typically aluminium pad metallization) or the package bonding surface (usually a plated leadframe post or finger) using an ultrasonic bonding process.

3.5
bonding surface
surface to which the wire is bonded, which may be any one of the following: 1) the die pad metallization or die surface metallization (e.g., MOSFET), 2) the package surface metallization (e.g., leadframe, substrate, post), 3) a bump (see also “reverse bond” and “bump”), or 4) a bonded stitch on die pad/flag or package surface metallization (see also “security bond” and “security loop”).

3.6
bonding process, thermosonic
bonding process in which two members are joined through the combined application of heat, pressure, and an ultrasonic oscillatory lateral motion.

3.7
bonding process, ultrasonic
bonding process in which two members are joined through the combined application of pressure and an ultrasonic oscillatory lateral motion.

3.8
bonding wire
wire that is bonded to a chip bonding surface in order to electrically connect the chip to any other point within the device package.

3.9
ribbon (wire)
flat wire (non-round).

Note 1 to entry: Throughout this test method the term “wire” covers both wire and ribbon (wire).

3.10
aluminium wire
aluminium alloy wire in which the aluminium content is typically 98 % or greater.

3.11
copper wire
copper alloy wire in which the copper content is typically 99 %, but also includes copper wire with a very thin coating of palladium or gold and palladium.

3.12
gold wire
gold alloy wire in which the gold content is typically 99 % or greater.

3.13
silver wire
silver alloy wire in which the silver content is typically greater than 85 % for integrated circuits (ICs) and greater than 75 % for light emitting diodes (LEDs).

3.14
midspan
location on the bonded wire that is approximately one half of the horizontal distance between the two bonds. (See Figure 1)

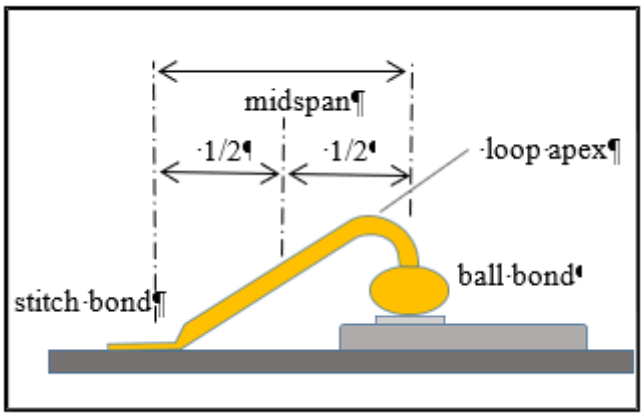

Figure 1 – Definition of midspan

3.15
outlier product
product that meets manufacturer specifications and user requirements but exhibits anomalous characteristics with respect to a normal population (an example of which is depicted by the histogram in Figure 2) and may be subject to a higher-than-normal level of failures in the user's application.

Note 1 to entry: For purposes of this document, all Wire Bond Pull Tests have only a minimum pull value requirement and no upper limit, thus the upper specification limit (USL) is not applicable.

Note 2 to entry: See also JESD50, "Special Requirements for Maverick Product Elimination and Outlier Management".

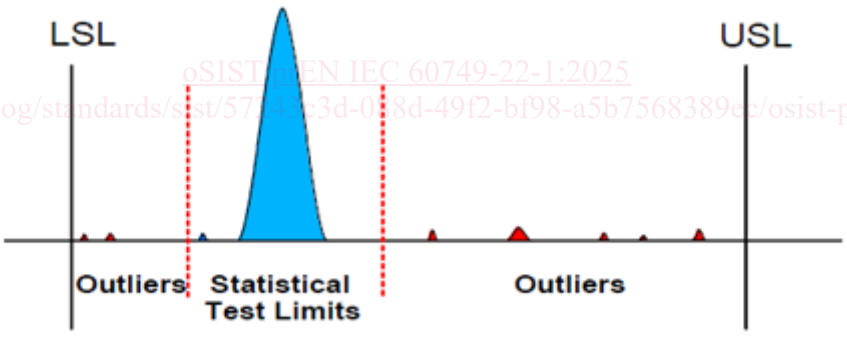

Figure 2 – Depiction of eight outliers, seven of which are outlier products

3.16
reverse bond

thermosonic bond for which the ball is placed on the package bonding surface and the stitch is placed on a bump on the die. This is also known as "stitch on ball".

3.17
bump
thermosonic ball bond from which the wire has been removed. It can be used as the underlying ball bond for reverse bonds on which the stitch (2nd bond) for the reverse bond is placed, or the ball bond placed on a stitch bond to form a security bond.

3.18
security bond
placing of a bump (see also “bump”) on top of a stitch bond to improve the mechanical strength of a stitch bond to withstand the shearing stress between the encapsulation material and the bonding surface.

Note 1 to entry: Security bonds are commonly used in surface mount LED (light emitting diode) packages which use non-filled encapsulants for the lens material that have higher coefficients of thermal expansion than silica filled encapsulants, and thus exhort higher shear stresses on the stitch bond.

3.19
security loop
security bond from which the wire has not been removed and the wire for the security loop is attached to the same bonding surface as a stitch bond.

3.20
wire bond pull, destructive
process in which an instrument pulls on a thermosonic or ultrasonic bonded wire until failure.

3.21
wire bond pull, non-destructive
process in which an instrument pulls on a thermosonic or ultrasonic bonded wire with a specified load that is below the minimum destructive pull value, such that no permanent damage or degradation is expected to be imparted on the wire.

3.22
wire bond pull force (destructive
force required to cause any of the following to occur: the bonded wire to break; one of the bonds to separate from a bonding surface; or one of the bonding surfaces to separate from the die, leadframe, or substrate.

4 Apparatus and material

4.1 Inspection equipment

An optical microscope system or scanning electron microscope with a minimum of 70X magnification is required to support the optical assessment of the resulting failure mode, such as whether the wire break was ductile or brittle or if the bond lifted from pad or leadframe/substrate with or without residues on pad or leadframe/substrate).However, a higher magnification may be necessary for verifying Failure Codes 1, 2, 3, 6, 7, 8, and 9 (see 5.5 for a detailed discussion of Failure Codes).

4.2 Workholder

The fixture used to hold the device, known as the “workholder” shall prevent any movement of the device during wire bond pull testing and shall allow positioning the hook for optimum force application to the wire.

4.3 Wire bond pull equipment

The apparatus shall consist of suitable equipment for applying a pulling force to the bonding wire as required in accordance with this test method until failure occurs within the wire, wire bond, or wire bonding surface. The equipment shall be capable of applying force at a constant rate. The equipment shall indicate the applied force in SI and/or English units and be calibrated over the full range of the expected values for the specific wire being pulled with an accuracy of ±5 % of the intended breaking load or ± 2.9 mN (± 0,3 gf), whichever is the greater tolerance. The required range of force values will vary by wire material and wire cross-section.

The pull tester manufacturer's recommended pulling tool travel speed for the wire material being tested should be used. To verify that the pull speed for a test was in an acceptable range, the output of the loadcell shall be reviewed to ensure that the strain rate was consistent throughout the test.

4.4 Pulling hook

The pulling hook should be made of a strong, rigid material that will not deform during pull testing. The diameter of the wire used to make the hook utilized to apply force to the interconnect wire shall be large enough and its final shape shall be such to ensure that the force applied by the hook distributes the pull force through the wire to the bonds and does not cut through the wire. Table 1 provides the minimum diameter for the pulling hook to ensure the above requirement.

Table 1 – Guidance for the minimum diameter of the pulling hook

Wire diameter	Hook diameter
≤50 μm (0,002")	Minimum of 2,0x wire diameter
>50 μm (0,002") to ≤125 μm (0,005")	Minimum of 1,5x wire diameter
>125 μm (0,005")	Minimum of 1,0x wire diameter

For ribbon wire, use the equivalent round wire diameter which gives the same cross-sectional area as the ribbon wire being tested. The flat portion of the hook (horizontal) should be > 1 ,25x the equivalent diameter of the ribbon wire being tested.

The hook shall be smooth (no sharp edges) and free of defects and contamination which could compromise the test results or damage the wire being pulled.

4.5 Bond pull clamp

For the clamp pull tests, the clamp used shall be able to apply enough force to the wire being pulled to hold it firmly such that it will not slip during the test. The clamp shall be large enough to firmly hold the diameter of the wire or width and thickness of the ribbon to be pulled such that it does not move when being pulled. The external shape and dimensions of the clamp shall be optimized to allow for it to clamp onto the wire to be pulled, but also minimize the chance of it touching and possibly damaging other wires on the device that are intended to be pull tested.

5 Procedure

5.1 Calibration

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

5.2 Visual examination of bonds to be tested after decapsulation

5.2.1 Applicability

In addition to being a manufacturing process monitor, this test method can also be used to assess bonds of encapsulated devices after soldering operations or after reliability stress testing. To do this, the encapsulation material needs to be removed in a manner that does not significantly degrade the wire, the bond, the bonding interface, or the bonding surface. Bond pull force values are often lower for bonds that have been decapsulated, and therefore cannot be compared to values for similar, unencapsulated bonds. If the decapsulation process is well controlled and repeatable, which is the case for gold wire, then this test method can be used for lot-to-lot comparison; however, it may be difficult to consistently control the decapsulation process for copper and silver wires to ensure the accuracy of the results. For copper (Cu) and silver (Ag) wires, the effectiveness of etch has been seen to vary due to the encapsulation

material and the level of reliability stress testing performed on the samples. See Annex B for additional information regarding the decapsulation process of devices with Cu and Ag wire bonds.

Bonds must also be examined to ensure that enough encapsulation material has been removed to allow for suitable placement of the pull hook.

5.2.2 Bond pad examination and acceptability criteria for both aluminium and copper bond pad metallization

If performing wire bond pull testing on a device which has been opened using wet chemical and/or dry etch techniques, the bond pads shall be examined to initially ensure that there is no absence of metallization on the bonding surface area due to chemical etching, and then ensure that wire bonds are attached to the bonding surface. Bonds on aluminium or copper bond pads with significant chemical attack or absence of metallization shall not be used for wire bond pull testing.

It is possible that 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), however, in these cases wire bonds are considered valid and shall be included in the pull data as a zero (0) pull force value.

5.2.3 Examination and acceptability criteria for Cu and Ag wire and connections (all bonds)

When performing wire bond pull testing on a device with copper or silver wires, the connection of the bond and wire shall be examined after decapsulation, both before or after the pull test to ensure that there is no significant loss of metal or other damage due to decapsulation process that might affect the results of the pull test. The pull result can be excluded for a copper bond or a copper wire with significant chemical attack or other damage due to the decapsulation process. Annex B provides additional information to assess what level of damage is acceptable.

5.3 Performing the wire bond pull test

5.3.1 Wire bond pull test used

Multiple wire bond pull tests are described in this document:

- wire pull (hook used to pull wire so that both bonds are stressed),
- ball pull (hook or clamp used to stress mainly the ball bond),
- stitch pull (hook or clamp used to stress mainly the stitch bond), and
- pull of wedge bonds (clamp or hook used to stress either one or both bonds).

Each of the pull tests and their variations are described below.

NOTE Not all bond pull tests give repeatable and/or reproducible results, as results may be affected by the geometry of the device and the device decapsulation results (if decapsulation is required). The determination of which wires and bonds are to be pulled within a device and by which pull test is determined by the qualification document that references this test method and should ensure that the pulling of all types of bonds is adequately addressed.

5.3.2 Hook pull method

5.3.2.1 Hook pull requirements and locations

The wire bond pull equipment shall pass all self-diagnostic tests before beginning the test. The wire bond pull equipment and test area shall be free of excessive vibration or movement. Examine the pull hook to ensure that the correct hook is used and to verify it is in good condition